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CONTENTS

Page

Striped Bass Spawning in the Sacramento and San Joaquin Rivers in Central California from 1963 to 1972 ..... Jerry L. Turner 106

Effects of Salton Sea Water on the Eggs and Larvae of *Bairdiella icistia* (Pisces: Sciaenidae) ..... Robert C. May 119

The Validity of Otoliths as Indicators of Age of Petrale Sole from California..... Paul A. Gregory and Tom Jow 132

Distribution, Harvest and Survival of American Wigeon Banded in California ..... Warren C. Rienecker 141

Notes

A Range Extension for the Logperch, *Percina macrolepida* in California ..... Gerald L. Boles 154

On the Foraging Distance and Prey Selection of Nesting Caspian Terns..... Robert E. Gill, Jr. 155

Helminth Parasites in American Coots from the Lower Colorado Riber..... Thomas J. Eley, Jr. 156

First Record of the Mohave Ground Squirrel (*Citellus mohavensis*) in Kern County, California David L. Chesemore and Dennis Carroll 158

Southern Range Extension of the Blue Rockfish, *Sebastes mystinus*; the Flag Rockfish, *S. rubrivinctus*; and the Shortbelly Rockfish, *S. jordani* Richard Klingbeil and Eric H. Knaggs 160

A Swimming Crab, *Euphylax dovii* Stimpson 1860, New to the Marine Fauna of California ..... Jack Q. Word 161

First Record of Albinism in the Leopard Shark (*Triakis semifasciata*) ..... W. I. Follett 163

ERRATA

Campbell, Gail, and Robson A. Collins. 1975. The age and growth of the Pacific bonito, *Sarda chiliensis*, in the Eastern North Pacific. Calif. Fish Game, 61(4): 181–200.

Page 187, paragraph 2, equation should read:

$$l_t = 76.87[1 - e^{-0.6215(t+0.410)}]$$

The same mistake is also present in Figure 4.

The length at age II should read 59.7 cm.

The last V should be VI.

IN MEMORIAM

Alan C. Taft

Alan C. Taft, Chief of the Bureau of Fish Conservation of the California Department of Fish and Game until his retirement on April 30, 1952, died on August 27, 1975, following a stroke. At the time he was a resident of Menlo Park, California.

Alan Taft was born in Rothsay, Minnesota, on April 20, 1897 and educated at Stanford University, where he received his A.B. in 1927 and his A.M. in 1928. He served with the U. S. Bureau of Fisheries (later the U.S. Fish and Wildlife Service) as an aquatic biologist from 1928 to 1937, both in Alaska and California.

In 1937 Alan was appointed Chief of the Bureau of Fish Conservation, predecessor of the Inland Fisheries Branch. He career in this position marked an outstanding chapter in the development of California's inland fisheries program. Under his guidance, fish planting procedures and equipment, new types of fish screens, a statewide system of stream and lake surveys, and a general investigative program were developed to meet the challenges created by the rapid population growth in California and attendant problems. At the time of his retirement, both the investigative and fish cultural programs in California were acclaimed nationally.

Promptly upon his retirement, the Food and Agricultural Organization of the United Nations engaged Alan to conduct a review of Finland's fisheries administration and legislation during the summer of 1952. In 1954–55, he was employed by the Foreign Operations Administration (later International Cooperation Administration) of the United States Government to conduct a survey of fishery resources in Ecuador and Bolivia and recommend a program for development of fishery industries. In 1955, he was again employed by ICA to carry out a survey of the present and potential fisheries of the Kingdom of Nepal.

Alan was recognized not only as one of the ablest and best informed fisheries administrators in the United States, but also an outstanding research biologist. He had a deep interest in the native fish fauna of California and was author or coauthor of a number of publications in *California Fish and Game* and other scientific journals. He was coauthor of *The Life Histories of the Steelhead Rainbow Trout and Silver Salmon,* chosen by The Wildlife Society as the most outstanding publication in wildlife ecology and management during 1954–55.

Alan was a life member of the American Fisheries Society and during his career a member of a number of other societies, including the American Association for the Advancement of Science, American Society of Ichthyologists and Herpetologists, The Wildlife Society, and Western Society of Naturalists.

Alan Taft leaves his wife Dena and his son Bruce. His many friends will miss him.—*Leo Shapovalov, California Department of Fish and Game (Retired), September 1975.*

Calif. Fish and Game 62(2): 106–118. 1976.

STRIPED BASS SPAWNING IN THE SACRAMENTO AND SAN JOAQUIN RIVERS IN CENTRAL CALIFORNIA FROM 1963 TO 1972

JERRY L. TURNER [1]
Bay-Delta Fishery Project
California Department of Fish and Game

Striped bass eggs and larvae were collected in the Sacramento and San Joaquin Rivers during spawning surveys from 1963 to 1972. Spawning was heaviest at water temperatures from 17.2 to 20 C. Most spawning in the San Joaquin Delta occurred from April 23, to May 25. Spawning in the Sacramento River above the Delta was primarily from May 10 to June 12. The middle of the spawning period in the Delta averaged 15 days earlier than in the Sacramento River. The time difference was greatest in years of high flow. Most spawning in the Sacramento River occurred from the City of Sacramento upstream to Colusa. Most spawning in the Sacramento-San Joaquin Delta occurred between Antioch and Venice Island where salinities during spawning have usually been less than 200 mg/1 TDS but occasionally have been up to 1,500 mg/1. Both eggs and larvae were more concentrated near the bottom than at the surface in the Sacramento River above the Delta. The survey in 1972 indicated almost all larvae in the Sacramento River upstream from Isleton are 6 mm or less in length. In 1972 about 55% of the season's spawning occurred in the Sacramento River.

INTRODUCTION

The two major spawning areas of striped bass in the Central Valley of California are the Sacramento River upstream from the Sacramento-San Joaquin Delta and the San Joaquin River and adjacent sloughs in the Delta (Calhoun, Woodhull, and Johnson 1950; Chadwick 1958; Farley 1966). Present and future water diversions may affect the survival of striped bass eggs and larvae in these areas. An understanding of the factors affecting the time and location of spawning is necessary to recommend means of modifying water development plans to protect striped bass. This report describes the understanding developed from several surveys conducted from 1963 to 1972.

METHODS

Striped bass eggs and larvae were collected by several methods. Plankton nets were used each spring from 1963 through 1966 in the Sacramento River and from 1963 to 1965 in the Delta. The nets had a 46 centimeter (18 inch) mouth and a 102 centimeter (40 inch) cone of 9 mesh per centimeter bolting cloth. Ten minute surface tows were made 2 to 3 times a week at selected locations. Farley (1966) described the methods and location of the sampling stations.

A 0.5 hp Moyno utility pump with a synthetic rubber helical rotor was used to collect continuous samples of eggs and larvae in the Sacramento River from 1967 to 1969 and in the San Joaquin River above the Delta in 1968. Eggs and larvae were pumped into a container where they were strained from the water by a fine mesh screen. At some locations, samples were taken from several depths. The catch was collected every 24 hours. Many samples could not be used because they overflowed when detritus clogged the screens.

[1] Present address: Jerry L. Turner, Box 27, Monkey Bay, Malawi, Africa. Accepted for publication July 1975.

Large cone-shaped tow nets were used in the Delta from 1966–1972 and in the Sacramento River in 1972. The nets were 3.2 m (10.5 ft) long with a mouth of 0.76 (2.5 ft) in diameter. In 1966 the front half of the net was constructed of 0.64 cm (1.4 inch) mesh nylon webbing. The back half was 7.9 mesh per cm nylon marquisette. From 1967 to 1972 the entire net was 7.9 mesh marquisette. Essentially all eggs are retained by this mesh, but many larvae shorter than 7 mm pass through it. All tows were 10 minutes and the volume of water strained was metered. Tows were diagonal from bottom to surface to obtain a sample integrated over depth.

Each station was occupied every second day during the sampling period, except when mechanical problems prevented sampling. The number of stations and sampling period varied from year to year (Table 1). Locations of sampling stations are shown for the Sacramento-San Joaquin Delta from 1966–1972 and for the Sacramento River above the Delta in 1972 (Figure 1).

All samples were preserved in formalin. The ages of the eggs collected from the Sacramento River from 1963 to 1969 were estimated through examination with a dissecting microscope and comparison with stages of development described by Mansueti (1958). The geographical origin of each egg was then estimated by multiplying its estimated age by the river

TABLE 1. **Sampling Methods Used in Striped Bass Egg and Larvae Studies.**

Sacramento River Above Delta

Year	Number of stations	Method	Depth	Sampling period
1965	3	Plankton net	Surface	April 27–June 23
1966	7	Plankton net	Surface	May 7–June 27
1967	1	Pump	Surface	May 6–July 1
1968	2	Pump	Surface, Bottom	May 21–June 14
1969	2	Pump	Surface, mid-depth, bottom	April 29–July 14
1972	17	Plankton tow net	Diagonal tow from bottom to surface	April 25–June 26

Sacramento-San Joaquin Delta

1965	6	Plankton net	Surface	April 27–June 23
1966	62	Plankton tow net	Diagonal tow from bottom to surface	April 8–June 30
1967	62	Plankton tow net	Diagonal tow from bottom to surface	April 25–June 28
1968	32	Plankton tow net	Diagonal tow from bottom to surface	April 3–June 28
1969	32	Plankton tow net	Diagonal tow from bottom to surface	April 17–July 10
1970	32	Plankton tow net	Diagonal tow from bottom to surface	April 21–June 28
1971	32	Plankton tow net	Diagonal tow from bottom to surface	May 24–July 15
1972	32	Plankton tow net	Diagonal tow from bottom to surface	April 28–July 15

San Joaquin River Above Delta

1968	8	Pump	Surface	March 28–May 14

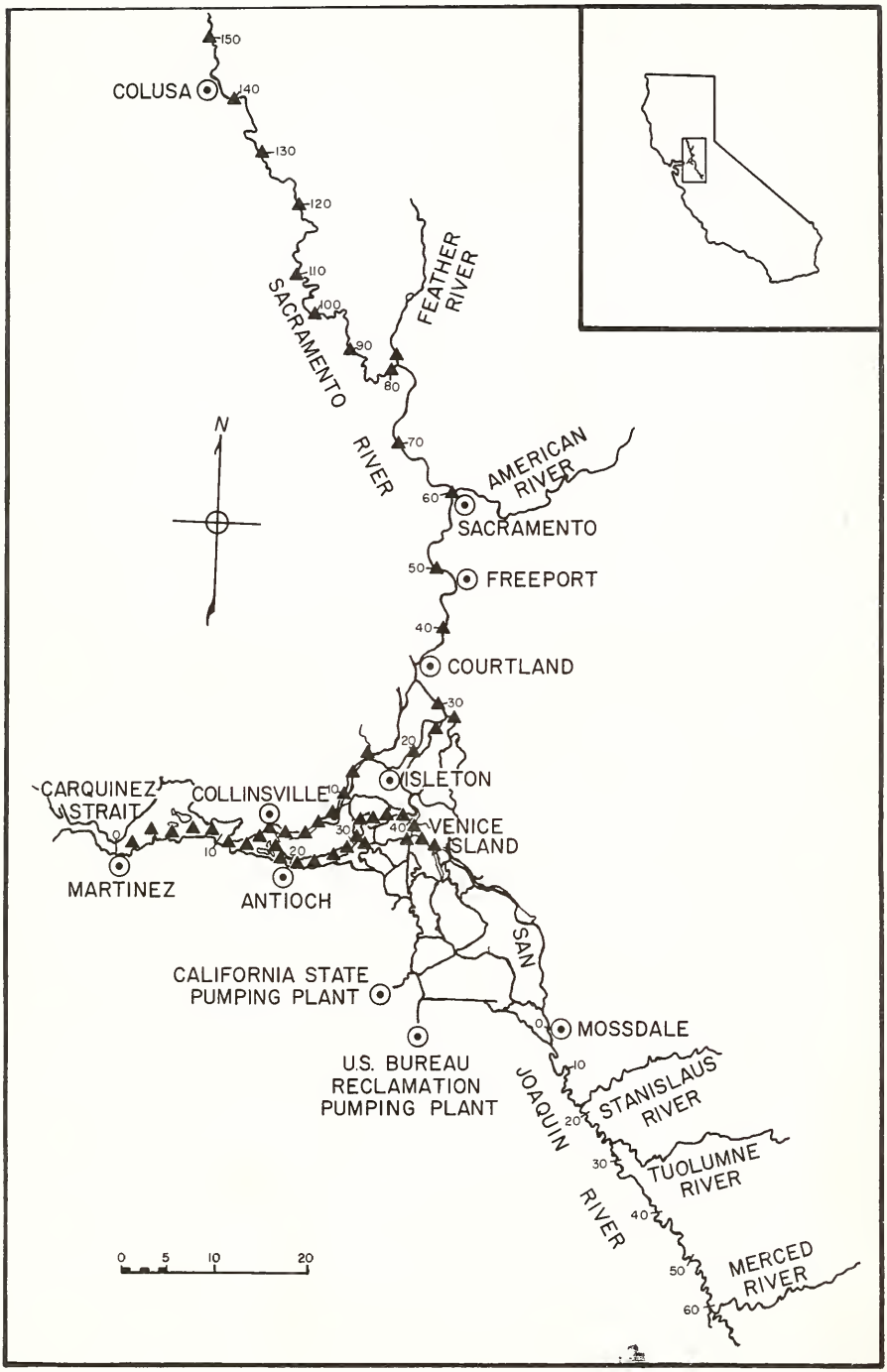

FIGURE 1. Map of study area showing location of sampling stations in 1972.

velocity upstream from the collection site which was provided by the California Department of Water Resources.

Eggs collected in the Sacramento River in 1972 and in the Sacramento-San Joaquin Delta in all years were merely classified as either less or greater than 8 hours old. Spawning was assumed to occur where eggs less than 8 hours old were collected.

Sampling in the Delta from 1966–1972 and in the Sacramento River in 1972 was more intensive and analyses were more refined than for the other surveys. Catches of eggs during these "intensive" surveys were weighted according to the water volumes in the river section represented by the sampling stations (weighted catch = egg catch/m^3 of water strained × water volume of sampling station). The California Department of Water Resources estimated water volumes for the Delta stations. I estimated volumes for the Sacramento River stations by multiplying mean cross sectional areas (estimated by the Department of Water Resources) by distances represented by the stations.

A water sample was taken with each sample of eggs and larvae. The electrical conductivity of each water sample was measured in the laboratory. Total dissolved solids (TDS) concentrations (mg/l) were estimated by multiplying electrical conductivity in micromhos by 0.64. This is an approximation as this constant varies with location and salinity. Most measurements of the constant in the study area fall between 0.5 and 0.7.

RESULTS

Time of Spawning

Most spawning in the Delta occurred between April 23 and May 25, with the possible exception of 1965 (Figure 2). In 1965, only 2,142 eggs were taken during the entire season, and 967 or 45.1% were caught the first sampling day (April 27). Spawning in the San Joaquin River above the Delta in 1968 occurred primarily from April 10 to May 9. In the Sacramento River, most spawning occurred between May 10 and June 12 in all years. The greatest deviations from this period were in 1966 and 1972 when 20 to 25% of the bass spawned before May 10, and in 1969 when about 25% spawned after June 12.

TABLE 2. **Mean Number Striped Bass Eggs per Two Collected at Various Water Temperatures in the Sacramento River in 1963, 1964, and 1965.** Only Eggs Eight Hours in Age or Less were Considered.

Water temperature F	Number of tows	Eggs per tow	Percent of total eggs per tow
56	10	0	--
57	14	.2	.4
58	36	0	--
59	39	.3	.6
60	70	1.6	3.5
61	52	1.2	2.6
62	55	1.1	2.4
63	64	8.8	19.2
64	71	2.6	5.7
65	52	8.2	17.9
66	66	14.5	31.6
67	32	2.7	5.9
68	35	4.4	9.6
69	25	.3	.6
70	3	0	--
71	1	0	--
72	1	0	--

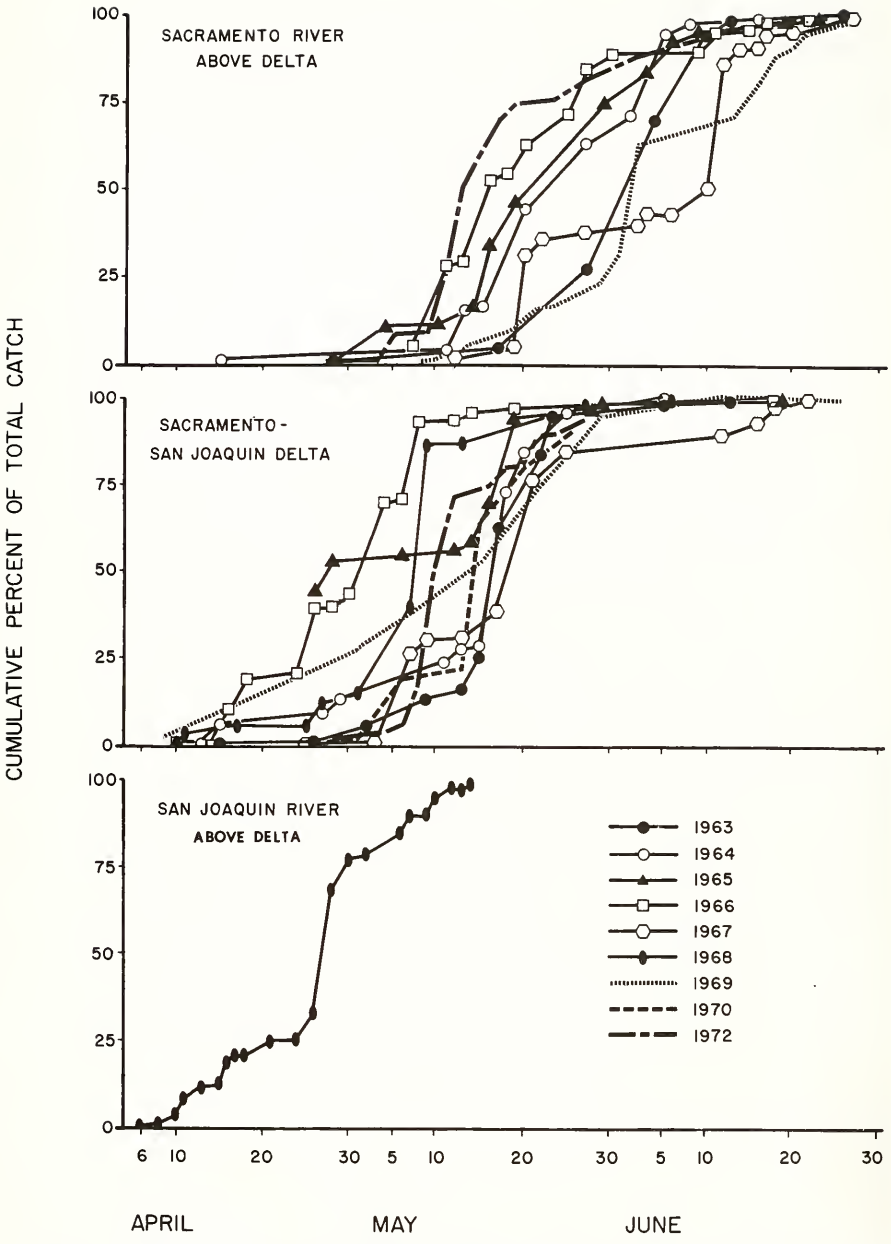

FIGURE 2. Cumulative percentage of striped bass spawning over time in various areas. Daily percentages for the Delta from 1966–1972 and for the Sacramento River in 1972 were estimated by dividing total weighted catches each day by the seasonal total weighted catch. Percentages for the other surveys were estimated by dividing the daily catch per unit effort by the sum of those statistics for the season. The cumulative percentage is a running sum of the daily percentages.

Water temperature was measured at the time of sampling in the Sacramento River from 1963 to 1965. Almost 90% of the spawning occurred from 17.2 to 20 C (63 to 68 F) (Table 2).

The time of the middle of the spawning period is correlated significantly with the mean monthly water temperature for both April and May in the Sacramento River (Table 3). The relationship is not significant for the Delta when all years are considered. However, discounting 1965, when 45.1% of the eggs were caught the first day, the relationship is highly significant there also.

TABLE 3. Relation Between Middle of Striped Bass Spawning Period and River Temperature.

Sacramento River Above Delta

Year	Middle[1] of spawning season	Water temperature[2]	
		April	May
1963	June 1	54.1	59.3
1964	May 23	58.2	63.7
1965	May 20	53.8	59.6
1966	May 16	57.6	65.9
1967	June 9	49.8	58.1
1969	June 2	55.7	60.7
1972	May 13	58.1	65.6
Correlation coefficient		−.78	−.83

Sacramento-San Joaquin Delta

Year	Middle of spawning season	Water temperature[3]	
		April	May
1963	May 16	57.9	64.5
1964	May 16	61.6	65.3
1965	April 28[4]	60.2	66.2
1966	April 30	65.4	69.3
1967	May 18	56.2	66.1
1968	May 8	64.3	66.8
1969	May 13	61.1	66.4
1970	May 14	60.8	66.8
1972	May 10	62.8	68.0
Correlation coefficient (with 65 data)		−.57	−.58
Correlation coefficient (without 65 data)		−.87	−.86

[1] Date when cumulative percentage of spawning reaches 50% for method of calculating, see caption to Figure 2.
[2] Mean of daily maximum and minimum water temperatures at Freeport; from U. S. Geological Survey.
[3] Mean daily water temperature at Contra Costa PG&E steam plant, Antioch.
[4] Only 2142 eggs caught during season of which 967 were taken on the first day (April 27).

The middle of the spawning period in the Sacramento River was 16, 7, 22, 16, 22, 20, and 3 days later than in the San Joaquin Delta for 1963 to 67, 69, and 72 respectively. The average difference was 15 days. The difference between the spawning periods was greatest when river flows were high ($r = 0.85$ when the difference is compared with May outflow at Chipps Island). This reflects the fact that as flows increase, the normal spring increase in temperatures is retarded more in the Sacramento River than in the San Joaquin Delta spawning area.

Location of Spawning

All eggs caught were assigned to 20 mile sections of the Sacramento River where they were calculated to have been spawned (Table 4). Farley (1966) estimated the spawning location in 1963 and 1964 based on the catch of both eggs and larvae; however, his aging of larval fish appears to have been biased. Hence, I recalculated the location of spawning in 1963 and 1964 based only on egg catches.

TABLE 4. **Percentage of Striped Bass Eggs Estimated to Have Been Spawned in 20-mile Segments of the Sacramento River[1].** Measured in River Miles Above the Confluence of the Sacramento-San Joaquin Rivers. Only Years in Which Samples Were Taken Throughout the Length of the River Were Considered[2].

River mile	1963	1964	1966	1972	Average
0– 20	0	.1	*	.2	.1
20– 40	10.1	15.2	.1	.3	6.4
40– 60	6.7	10.0	.3	5.5	5.6
60– 80	3.8	18.1	8.8	20.3	12.8
80–100	13.4	4.2	68.6	30.4	29.1
100–120	3.8	22.9	18.3	34.2	19.8
120–140	54.8	12.9	3.1	9.0	20.0
above 140	7.3	16.5	.8	.1	6.2
Approximate sample size of eggs	2,400	4,700	5,500	186,000	
Midpoint of spawning (river mile)	124	102	92	96	

* No stations below river mile 26.

[1] In 1972 spawning was assumed to occur where eggs ≤8 hours old were collected. Percentages in that year were calculated by dividing the season's total weighted catch in each section by the grand total for all sections. In 1963, 1964, and 1966, the geographical origin of each egg was estimated by multiplying its estimated age by the river velocity upstream. Percentages were calculated by dividing the total eggs assigned to each station by the total examined.

[2] The proposed intake site for the Peripheral Canal is approximately at mile 40.

The middle of the spawning area was assumed to be the river mile above and below which 50% of the spawning was calculated to occur. This point varied from river mile 92 in 1966 to 124 in 1963.

All striped bass eggs caught in the Delta were assigned to 5 mile sections upstream from Martinez (Table 5). The bulk of spawning occurred in the San Joaquin River between Antioch (river mile 21) and Venice Island (river mile 38). A moderate amount of spawning apparently occurred below Antioch in 1967 and 1969, although high flows in those years might have transported young eggs farther seaward.

In 7 of the 9 years in which eggs were sampled in the Delta, more than 80% of all young eggs were collected where total dissolved solids (TDS) were less than 200 mg/l. However, in 1968 and 1972 salinity intruded into the spawning area and sizable numbers of eggs were laid at higher TDS levels (Table 6).

TABLE 5. **Percentages of Striped Bass Eggs Estimated to Have Been Spawned in 5-mile Segments of the San Joaquin River and Suisun Bay.** Measured in River Miles Upstream from the City of Martinez[1].

River mile	1966	1967	1968	1969	1970	1971	1972	Average
0– 5	0	.9	0	2.7	0	0	0	.5
5–10	.3	3.9	0	1.7	0	0	0	.8
10–15	.3	11.8	.1	6.1	.2	2.3	.1	3.0
15–20	.1	29.9	1.6	20.6	2.3	1.3	.5	8.0
20–25	11.7	25.4	28.5	58.2	17.7	53.8	53.0	35.5
25–30	61.0	9.6	36.2	7.9	14.8	42.6	38.0	30.0
30–35	16.4	1.7	26.1	1.9	2.1	0	4.5	7.5
35–40	9.7	13.6	7.1	0	59.8	0	3.3	13.4
40 plus	.5	3.1	.5	.9	3.2	0	.7	1.3
Mean Delta outflow during May (000's cfs)	10	74	6	64	10	24	6	

[1] Spawning was assumed to occur where eggs ≤8 hours old were collected. Percentages were calculated by dividing the season's total weighted catch in each section by the grand total for all sections.

TABLE 6. **Percentages of Total Striped Bass Eggs Estimated to Have Been Spawned in Various Ranges of Total Dissolved Solids in the Sacramento-San Joaquin Delta[1].**

Range of total[2] dissolved solids	1964	1965	1966	1967	1968	1969	1970	1971	1972
<200	84.2	100.0	96.7	99.6	38.8	94.2	89.9	100.0	5.1
200– 500	15.5	0.0	3.3	.4	37.7	5.8	7.7	0.0	20.7
500– 600	.3	0.0	0.0	0.0	20.7	0.0	2.0	0.0	29.6
600– 700	0.0	0.0	0.0	0.0	.1	0.0	.5	0.0	7.0
700–800	0.0	0.0	0.0	0.0	.5	0.0	0.0	0.0	1.9
800–900	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	9.2
900–1,000	0.0	0.0	0.0	0.0	.1	0.0	0.0	0.0	0.4
1,000–1,200	0.0	0.0	0.0	0.0	.4	0.0	0.0	0.0	25.3
1,200–1,400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
>1,400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8

[1] Spawning was assumed to occur where eggs ≤8 hours old were collected. Percentages for 1966–72 were estimated by dividing the season's total weighted catch of eggs ≤8 hours old in each salinity range by the season's grand total weighted catch. Percentages for 1964 and 1965 were estimated by dividing the season's catch/m³ of water strained in each salinity range by the sum of the catch/m³ for all salinity ranges.
[2] Salinity concentrations were estimated by measuring electrical conductivity in micromhos and multiplying by 0.64 to estimate salinity in mg/l TDS.

Most spawning in the San Joaquin River above the Delta in 1968 apparently occurred between the mouths of the Stanislaus and Merced Rivers (Table 7). Pumps located inside the mouths of the Stanislaus, Tuolumne, and Merced Rivers caught only one egg. It was taken in the Stanislaus River. Most of these eggs from the San Joaquin River above the Delta were collected at TDS ranging from 600–800 mg/l (Table 8); however, 94% of these eggs were dead (no cell division or broken embryos). In the Sacramento River where TDS levels were always less than 200 mg/l, only 46% of the eggs collected by the pumps were dead.

TABLE 7. Percentages of Striped Bass Egg Catch[1] at Sampling Stations in 1968 in the San Joaquin River Upstream from Mossdale.

Station	Percent
Mossdale—River mile 59	1.4
Stanislaus River	0.1
Highway 132 Crossing—River mile 82	58.0
Tuolumne River	0.0
Patterson—River mile 104	39.6
Crows Landing—River mile 113	0.8
Merced River	0.0
Gustine—River mile 130	0.0

[1] Sample size = 848 eggs

TABLE 8. Percentages of Total Striped Bass Eggs Collected in Various Ranges of Total Dissolved Solids in the San Joaquin River Above the Delta.

Range of total dissolved solids (mg/l)	1968
200– 500	.7
500– 600	4.8
600– 700	30.6
700– 800	52.2
800– 900	6.9
900–1,000	3.3
1,000–1,200	1.5
>1,200	0

Vertical and Lateral Distribution of Eggs and Larvae in the Sacramento River

In 1968 the vertical and lateral distribution of striped bass eggs and larvae was measured in the Sacramento River at Courtland (river mile 35) and just above the City of Sacramento (river mile 61). Tidal effects in this section of the river are negligible. At Courtland, pumps obtained samples 0.9 m (3 ft) under the surface and 0.9 m (3 ft) off the bottom near the center of the channel where the river was 7 m (23 ft) deep, and 0.9 m (3 ft) below the surface near shore where the river was 1.5 m (5 ft) deep. At Sacramento samples were taken 0.9 m (3 ft) below the surface and off the bottom near the center, where the river was 5.5 m (18 ft) deep.

At Sacramento 91% of the catch was eggs, while at Courtland the larvae constituted 97% of the catch. Obviously most eggs hatched into larvae between these two stations.

At Sacramento the mean concentration of eggs at the surface was less than half that at the bottom (0.31 vs. 0.76 eggs/m^3). Larvae had a similar distribution pattern at Sacramento, with the mean concentrations being 0.028 and 0.074/m^3 at the surface and bottom, respectively.

Virtually all larvae caught at Courtland were at the bottom station in mid-channel. Mean concentrations were 0.001 and 0.961/m^3 at the surface and bottom, respectively, in mid-channel and 0.022/m^3 near shore.

Length of Larvae in Sacramento River

In 1972, the larval fish were measured. Almost all larvae caught upstream from Isleton were 6 mm or less SL (Table 9). Obviously most larvae coming from the Sacramento River are swept into downstream tidal areas when they are small.

TABLE 9. Weighted Length Frequency of Young Striped Bass Caught in 1972 in the Sacramento River Upstream From Iselton[1].

Length (mm)	Weighted catch	Percent total
3	108,489	10.4
4	285,497	27.5
5	605,362	58.2
6	38,763	3.7
7	248	
8	375	
9	0	
10	135	
11	219	
12	267	0.2
13	266	
14	194	
15	136	
16	51	
17	99	
18	46	
Total	1,040,147	

[1] Recent net efficiency tests indicate that many larvae shorter than 7 mm passed through the mesh.

Relative Amount of Spawning in the Two River Systems

In 1964, Farley (1966) estimated that 66% of the striped bass spawning occurred in the Sacramento River and 33% occurred in the Delta.

Estimates were made in 1972 for both river systems by weighting catches according to the volume of water represented by the sampling stations. Only eggs (all ages) were considered in these estimates. The estimates indicate that 55% of the spawning occurred in the Sacramento River and 45% in the Sacramento-San Joaquin Delta.

DISCUSSION

Results presented in this paper will help develop criteria for operating water projects in a manner that will benefit the Sacramento-San Joaquin Estuary's striped bass population. Presently, large amounts of water from the Sacramento River are transported in existing channels across the central portion of the Delta to export pumps at State and Federal facilities near Tracy (Figure 1). Eggs, larvae, and young fish are diverted along with the water. Fish screens at the intake are efficient only in removing those fish large enough to swim well. They salvage from 25 to 90% of young striped bass in various length groups between 1.3 and 5.1 cm (0.5 and 2 inches) (Hallock, Iselin, and Fry 1968; California Departments of Water Resources and Fish and Game, 1973). Few larvae approaching the screen are salvaged (California Departments of Water Resources and Fish and Game, 1973), and presumably few eggs are salvaged. The diversion of striped bass eggs by the export pumps has been estimated to be 15 to 30% of the total spawned (Delta Fish and Wildlife Protection Study, 1964).

One approach to minimizing the diversion of striped bass is to transfer water around the Delta rather than through it. The Peripheral Canal, which would divert the water from the Sacramento River above the Delta was recommended in part to do that.

While the Canal would eliminate the diversion of eggs and larvae from the San Joaquin River, a major problem would still remain in that eggs produced in the Sacramento River above the proposed intake to the Canal would reach the Canal as eggs or larvae less than 6 mm long. No screen presently available could remove these eggs and larvae from the water being diverted.

This problem could be solved if water diversions were curtailed during the period when eggs and larvae pass the Canal. My study shows that curtailment between May 10 and June 12 each year would cover most spawning. Briefer periods of curtailment could be effective, if they were timed to coincide with the actual passage of eggs and larvae. Such shorter curtailments would have to be based on monitoring of egg and larval abundance each spring, as the exact time of spawning is not predictable.

The effect of diverting eggs and larvae is difficult to define. Eggs, larvae, and young of prolific fish such as striped bass, experience high natural mortality, so 100% curtailment is obviously not essential to maintain the population. However, the number of young bass surviving until mid-summer is closely correlated with environmental conditions, and losses of eggs and young in diversions may contribute to this correlation (Turner and Chadwick 1972). Hence, the diversion of eggs and larvae may have a significant effect, but additional information on survival is necessary to evaluate any such effect.

The area where striped bass spawn in the Sacramento River is probably affected less by runoff than indicated by prior analyses. Calhoun, Woodhull, and Johnson (1950) theorized that the spawning location of striped bass in the Sacramento River was related to how fast the river warms in the spring. The river warms slowly when runoff is high; hence, under their theory, bass would spawn farther upstream in those years than in years of low runoff. Farley's (1966) analysis of egg and larval catches supported this theory. He found that spawning was much farther upstream in 1963, a wet spring, than in 1964, a dry spring.

My recalculation of spawning location in 1963, based only on egg catches, substantiated that the spawning location was farther upstream in 1963 than in 1964. The difference though was substantially less than indicated by Farley's calculations. Also, results from 1963, 1964, 1966, and 1972 do not demonstrate a consistent relationship between spawning location and river discharge (Table 10).

TABLE 10. **Striped Bass Spawning Location vs. Sacramento River Discharge.**

Year	Mean April–May flow at Sacramento (cfs)	Estimated midpoint of spawning (distance in miles above Collinsville)
1963	52,205	124
1964	13,230	102
1966	17,960	92
1972	12,985	96

In 1972, the estimated midpoint of spawning was river mile 96, but two changes in methodology bias the 1972 estimate downstream relative to the other years. (1) Eggs were assumed to be spawned where they were caught in 1972 rather than back tracked to some point upstream based on their age and current velocity. (2) Catches were weighted according to the water volume in the section of the river represented by the sampling station only in 1972, and the downstream stations tend to represent larger volumes than those represented by the upstream stations.

In the Delta, striped bass generally spawn where the water is very fresh (<200 mg/l TDS). At least in the short run though, water that fresh is not essential, as spawning occurred in approximately the same location in 1968 and 1972, despite ocean derived salinities reaching 1,500 mg/l TDS. Laboratory studies have indicated salinities up to 1,000 mg/l TDS do not affect egg survival adversely (Turner and Farley 1971), and field collections provided evidence that salinity intrusion did not influence egg survival in the Delta in 1972 (Table 11). The cause of the observed 94% mortality of eggs collected in the upper San Joaquin River in 1968, where TDS levels were 600–800 mg/l, is unknown. Eggs incubated in water from that reach of the river did not experience an unusual mortality (Turner and Farley 1971).

TABLE 11. **Percentages of Eggs Dead When Collected at Various Salinity Ranges in the Delta in 1972.**

TDS	Total weighted catch	Percent dead
<200	480,074	22.5
200– 500	1,390,010	14.4
500– 600	2,308,725	19.9
600– 700	390,520	8.3
700– 800	156,625	13.0
800– 900	418,562	10.2
900–1,000	41,642	7.0
1,000–1,200	2,120,384	21.9
1,200–1,400	66,627	19.1
>1,400	129,504	18.1
Average	7,502,673	18.2

While salinity within the ranges discussed above apparently does not increase egg mortality and has at most a limited short term effect on the location of spawning, the longer term effect of such salinities is uncertain. Striped bass have a pronounced tendency to return to the same spawning area each year (Chadwick 1967), and thus might respond little to occasional less than optimum salinity conditions. Yet, regular occurrence of the same salinities could reduce spawning in the area gradually, due to accumulative effects of either small differences in survival or migratory preferences.

The possibility of such a reduction in spawning related to salinity is suggested by several facts. One fact is tag returns suggest spawning in the lower San Joaquin River has already declined during the past 25 years. Striped bass tag returns from the Sacramento River spawning area increased from 3% of the total in 1950 to 7% in the years 1958–64 (Chadwick 1967). During the same period, returns from the San Joaquin Delta decreased from 10% to only 1% of the total. These trends suggest that

spawning striped bass have shifted from the Delta to the Sacramento River. This shift presumably reflects some deterioration in habitat quality in the Delta.

Secondly, striped bass universally spawn in essentially freshwater, although in a numer of estuaries they do spawn immediately upstream from the limits of ocean salinity intrusion, as they do in the lower San Joaquin River.

Finally, striped bass sometimes do respond to water quality while seeking a place to spawn. This occurs farther up the San Joaquin River where migrating bass are repelled by water from the upper San Joaquin drainage having a salinity greater than about 350 mg/l TDS (Radtke and Turner 1967).

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EFFECTS OF SALTON SEA WATER ON THE EGGS AND LARVAE OF *BAIRDIELLA ICISTIA* (Pisces: Sciaenidae) [1]

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In laboratory experiments, eggs and early larvae of the sciaenid fish *Bairdiella icistia* survived well in sea water but displayed extremely poor survival in water from the Salton Sea. Mortality in Salton Sea water was expressed mainly among hatched larvae prior to complete yolk absorption. Experiments conducted in both natural and artificial sea water and Salton Sea water indicated that this poor survival was related to the unusual ionic composition of the Salton Sea.

INTRODUCTION

This paper investigates the effect of the chemical composition of water from the Salton Sea, a saline lake in Southern California, on the eggs and larvae of *Bairdiella icistia* (Jordan and Gilbert), a fish which has existed in that lake since it was introduced there in 1950 (Walker, Whitney, and Barlow 1961). The salinity of the Salton Sea is gradually rising (Carpelan 1961*a*, U. S. Dept. Int. and Resour. Agency Calif. 1969), and concern has been expressed that the fish fauna of the Sea, which supports an important recreational fishery, will suffer as upper salinity tolerance limits are exceeded (Walker, Whitney, and Carpelan 1961). Lasker, Tenaza, and Chamberlain (1972) studied the ability of bairdiella eggs and larvae to tolerate elevated salinities of Salton Sea water and found that a salinity of 40 $^{o}/_{oo}$ severely inhibited survival. The purpose of the present work was to determine to what extent this tolerance limit was influenced by the peculiar ionic composition of Salton Sea water (Carpelan 1961*a*, Young 1970).

METHODS

Adult bairdiella were captured in the Salton Sea, transported to La Jolla, California, and maintained in sea water at the Southwest Fisheries Center. Gonadal maturation was induced in captive fish by controlling photoperiod and temperature, and spawning was induced by hormone injections, as described elsewhere (Haydock 1971, May 1975). All eggs and larvae used in the present experiments were obtained from fish which had been held in sea water for at least 1 year.

First Experiment

Salton Sea water (SSW) having salinity of about 36 $^{o}/_{oo}$ was collected along the southwest shore of the Sea 2 days before the experiment (in May 1970) and filtered through activated charcoal to remove dissolved organic matter. Ordinary sea water of 33 $^{o}/_{oo}$ was taken from the Southwest Fisheries Center sea-water system and passed through a cartridge filter (CUNO aquapure filter). A portion of each of the two batches of water was also passed through membrane filters (HA Millipore, 0.45 μm pore size) shortly before the experiment, and another portion was not membrane-filtered. Even after charcoal and membrane filtration, SSW usually has a slight yellow-green hue, probably indicating the presence of a persistent dissolved organic fraction.

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The bairdiella eggs were stripped and artificially fertilized, following techniques described by May (1975), in the four different water types and incubated at 22 C (72 F) without aeration in 300 ml (0.08 gal) circular Kydex containers described by May (1971). Antibiotics were added to the incubation media (May 1975). The mortality of unfed larvae after hatching was recorded, but no records of fertilization or hatching success were kept for this experiment.

Second Experiment

This experiment was conducted in December 1971, to compare embryonic and larval survival in SSW and sea water, and in artificial SSW and artificial sea waters of three salinities. The artificial waters were used to eliminate the possibility that the results in natural SSW may have been influenced by the presence of dissolved organic material or some toxic contaminant. A quantity of SSW (salinity approximately 36 °/₀₀) was collected along the southwest shore of the Salton Sea on 29 April 1971 and passed through activated charcoal and membrane filters before being stored in the dark at room temperature; this water was membrane-filtered again just before the experiment. Sea water obtained from the Southwest Fisheries Center seawater system was membrane-filtered shortly before the experiment. Artificial waters with salinities of 25, 35, and 45 °/₀₀ were prepared by dissolving reagent grade laboratory salts in deionized water. In the case of the artificial waters the term "salinity" is used here to refer to the total weight in grams of the salts dissolved in one liter of water. Only the seven major ions were used in the artificial formulations (Table 1); these constitute by weight well over 99% of the dissolved salts in sea water (Kester, Duedall, Conners, and Pytkowicz 1967).

TABLE 1. **Formula for Artificial Sea Water and Artificial Salton Sea Water.**

Salt	Amount of salt added (mg/liter)		
	Artificial sea water 45°/₀₀	Artificial Salton Sea water	
		35°/₀₀	45°/₀₀
$CaCl_2$	1468	2871	2999
$MgCl_2 \cdot 6H_2O$	13889	8507	11078
KCl	947	359	471
NaCl	30682	15790	21385
$NaHCO_3$	251	214	278
Na_2SO_4	5148	11781	14686

The composition of natural sea water given by Kester *et al.* (1967) was used as the basis for the artificial sea water formulation. A solution of 45 °/₀₀ was prepared (Table 1), and the two lower salinities were made by dilution. Analyses of the ionic composition of different samples of SSW made by different laboratories do not always agree (Young 1970); rather than averaging a number of recent chemical determinations on SSW to arrive at a "best estimate" of the ionic proportion of the Sea, I used the sample collected on 29 April 1971 (at the peak of the bairdiella spawning season) both as a control and as a standard for the preparation of artificial SSW. The ionic composition of this sample (Table 2) served as the basis for the 35 °/₀₀ artificial SSW, from which the 25 °/₀₀ water was prepared by dilu-

tion. When SSW evaporates, some calcium and sulfate precipitate out (Lasker *et al.* 1972) so that at elevated salinities the ionic proportions are somewhat altered. Artificial SSW of 45 °/₀₀ contained a precipitate (presumably gypsum, $CaSO_4 \cdot 2H_2O$) when the salts were added in the same proportions as at the lower salinities. The chemistry of SSW has not been comprehensively studied (see Hely, Hughes, and Irelan 1962, Pomeroy and Cruse 1965), and a formula for SSW of 45 °/₀₀ was constructed on the basis of the limited information available. It was assumed that the calcium concentration remained constant between 36 and 45 °/₀₀ (Pomeroy and Cruse 1965) and that the SO_4^{2-}/Cl^- ratio decreased in proportion to the increase in salinity in the same manner that it did in the evaporated batch of SSW whose ionic composition is described by Lasker *et al.* (1972). No precipitate formed when the salts were mixed according to the formula arrived at in this manner (Table 1).

TABLE 2. **Ionic Composition of Sea Water and Salton Sea Water Used in the Second Experiment.** The composition of sea water was calculated for a salinity of 34.24‰ assuming the same ionic proportions as given by Kester *et al.* (1967) for natural sea water at 35‰. The Salton Sea Water was collected on 29 April 1971 and analyzed by Edward S. Babcock & Sons, Riverside, California.

	Ionic concentrations in mg/liter	
	Sea water	Salton Sea water
Cations		
Ca^{2+}	404	1080
Mg^{2+}	1264	1060
Na^+	10508	10000
K^+	378	196
Anions		
HCO_3^-	139	162
SO_4^{2-}	2648	8300
Cl^-	18899	15158
Total	34240	35956

The pH of the artificial waters was similar, and their dissolved oxygen content decreased at higher salinities in a comparable fashion for artificial sea water and artificial SSW (Table 3). The freezing point depression of SSW (measured by the melting point method of Gross 1954) was less than that of sea water, both natural and artificial (Table 3).

Eggs were stripped and artificially fertilized in sea water, SSW, and the artificial waters. Antibiotics again were added to the incubation media. One hundred fertilized eggs were transferred to each of three replicate recirculating incubators (May 1975) for each type of water. The percentage of eggs fertilized was determined by counting cleaving eggs in random samples, and the incubation time, percentage of eggs hatching, and survival of unfed larvae were recorded as described elsewhere (May 1975). The temperature was 24 ± 0.2 C (75 ± 0.4F) throughout. The activity of bairdiella spermatozoa in the various water types was studied by methods previously described (May 1975).

TABLE 3. **Freezing Point Depression, Dissolved Oxygen Content, and pH of Various Water Types Used in the Second Experiment.** The water was well aerated at 24 C prior to measurement of dissolved oxygen and pH.

Water type	Salinity (‰)	Freezing point depression (C)	Dissolved oxygen (ml/liter)	pH
Natural sea water	34	1.85±.11*	5.01	8.21
Natural Salton Sea water	36	1.65±.02	----	----
Artificial sea water	25	1.33±.60	5.19	8.23
	35	1.80±.07	4.84	8.30
	45	2.34±.10	4.69	8.27
Artificial Salton Sea water	25	1.20±.06	5.01	8.27
	35	1.58±.12	5.01	8.29
	45	2.01±.09	4.59	8.17

* Mean ± standard deviation, N = 4

RESULTS

First Experiment

Larvae showed high mortality between hatching and Day 2 in both batches of SSW, while in sea water 80 to 95% of the larvae were still alive on Day 2 (Figure 1). Larvae in sea water started dying on Day 5, and a few survived until Day 7. Membrane filtration of SSW and sea water increased larval survival noticeably. Ciliate protozoans were seen as early as the day after fertilization in the water that had not been membrane-filtered, but were never found in the filtered water. Only 5% of the larvae in the membrane-filtered SSW were alive at the time of complete yolk absorption, and one larva survived to Day 5.

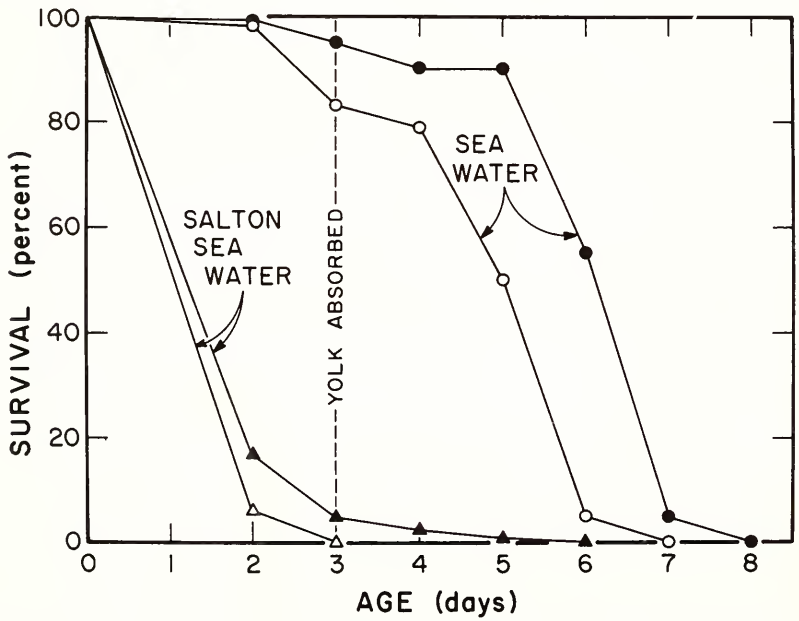

FIGURE 1. Survival of larvae in the first experiment. Closed symbols represent larvae in membrane-filtered water, open symbols represent those in water which was not membrane-filtered. Each curve is based on approximately 80 larvae. The temperature was 22 C, and the larval yolk supply was exhausted within 3 days after hatching.

Second Experiment

Fertilization success was higher in natural Salton Sea water than in natural sea water (Table 4). It is possible that the high calcium content of Salton Sea water aids fertilization (Yanagimachi and Kanoh 1953). In artificial sea water, fertilization was more successful in a salinity of 25 °/₀₀ than in 35 or 45 °/₀₀, while in artificial Salton Sea water fertilization was most successful in 35 °/₀₀. At 35 and 45 °/₀₀, more eggs were fertilized in SSW than in sea water. Haydock (1971) reported that there was greater spermatozoan activity in Salton Sea water, but in the present study no significant differences were detected in the intensity or duration of spermatozoan activity in SSW as opposed to ordinary sea water, either natural or artificial.

TABLE 4. **Fertilization Success in Various Water Types in the Second Experiment.** N is the number of eggs in the sample examined for fertilization.

Water type	Salinity (°/₀₀)	Percentage fertilized	N
Natural sea water	34	53.6	181
Natural Salton Sea water	36	72.9	221
Artificial sea water	25	79.0	200
	35	46.0	222
	45	45.1	333
Artificial Salton Sea water	25	59.1	340
	35	77.9	195
	45	60.3	150

TABLE 5. **Percentage of Fertilized Eggs Hatching in Various Water Types in the Second Experiment.** Values are listed for three replicate groups of eggs (a, b, and c) in each water type, along with mean values calculated from the replicates. "Normal hatch" is defined as the percentage of eggs giving rise to morphologically normal larvae, and "viable hatch" is the percentage giving rise to morphologically normal larvae capable of surviving to complete yolk absorption.

Water type	Salinity (°/₀₀)	Total hatch				Normal hatch				Viable hatch			
		a	b	c	$\bar{x}$	a	b	c	$\bar{x}$	a	b	c	$\bar{x}$
Natural sea water	34	75.5	87.1	86.4	83.0	51.1	68.8	50.5	56.8	47.0	63.3	46.5	52.3
Natural Salton Sea water	36	82.7	87.2	90.9	86.9	70.4	58.5	71.7	66.9	4.2	3.5	4.3	4.0
Artificial sea water	25	79.6	90.2	86.6	85.5	65.9	70.7	72.2	69.6	64.6	69.3	70.8	68.2
	35	79.1	67.8	82.9	76.6	62.8	51.7	52.6	55.7	51.5	42.4	43.1	45.7
	45	53.3	56.8	53.3	54.5	27.2	28.4	22.8	26.1	15.8	17.3	13.5	15.5
Artificial Salton Sea water	25	56.3	51.0	50.0	52.4	38.5	31.3	39.1	36.3	25.4	20.5	25.8	23.9
	35	77.1	70.2	77.8	75.0	67.7	61.7	66.7	65.4	0	0	0	0
	45	67.0	60.9	58.7	62.2	39.3	44.6	33.9	39.3	0	0	0	0

Eggs sank in artificial sea water at 25 and 35 °/₀₀, as well as in artificial SSW of 25 °/₀₀, but floated in all other water types. The percentage of eggs hatching was plotted on a probability scale against time on an arithmetic scale (Figures 2, 3, and 4) to disclose whether hatching was normally distributed (Sokal and Rohlf 1969). Only in 25 °/₀₀ artificial SSW, and possibly in 45 °/₀₀ artificial sea water, was there a convincing straight-line relationship indicating a normal distribution of hatching time; in other cases an inflection occured, suggesting that the hatching of certain eggs was delayed, and this seems more pronounced in the various sea waters than in SSW. Whitney (1961*a*) published a hatching curve for bairdiella larvae in SSW at 22–23 C (72–74 F); it shows that hatching was distributed normally over about a 4-hour period. The time required to reach hatching does not necessarily reflect developmental rates *per se*, since hatching is a separate process involving both enzymatic degradation of the chorion and muscular contractions by the embryo (Blaxter 1969). Evidently, this process is affected differently by sea water and by SSW.

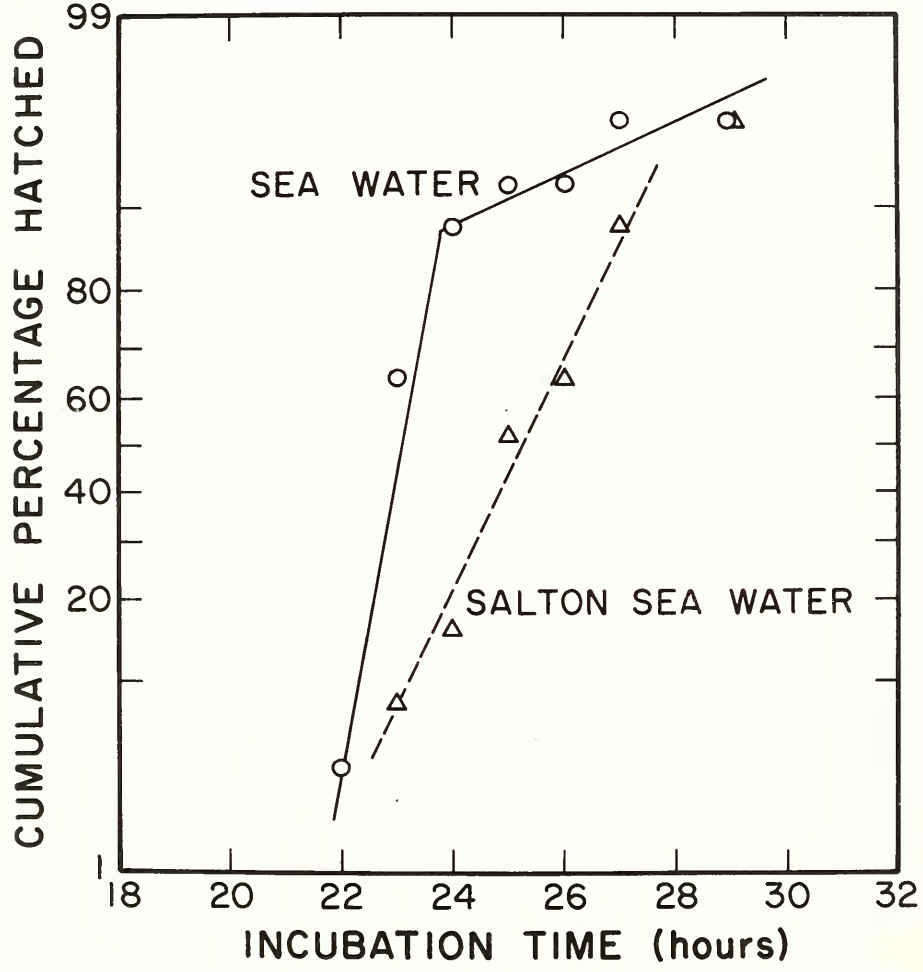

FIGURE 2. Pattern of hatching in natural sea water and Salton Sea water, second experiment. The cumulative percentage of hatched larvae is plotted on a probability scale against time on an arithmetic scale, and lines were fitted by eye. The temperature was 24 C.

The percentage of fertilized eggs that hatched successfully was comparable in natural SSW and natural sea water, generally being between 80 and 90% (Table 5). Eggs in artificial sea water showed a decline in hatching success with increasing salinity. Eggs in artificial SSW showed similar hatching success except at 25 °/$_{oo}$, where only slightly more than 50% hatched as compared with between 80 and 90% in artificial sea water (Table 5). The lower percentage total hatch in artificial SSW at 25 °/$_{oo}$ was accounted for mainly by eggs that developed to the hatching stage but failed to hatch; in other salinities, most of the embryonic mortality took place early in development, before any pigmentation had appeared.

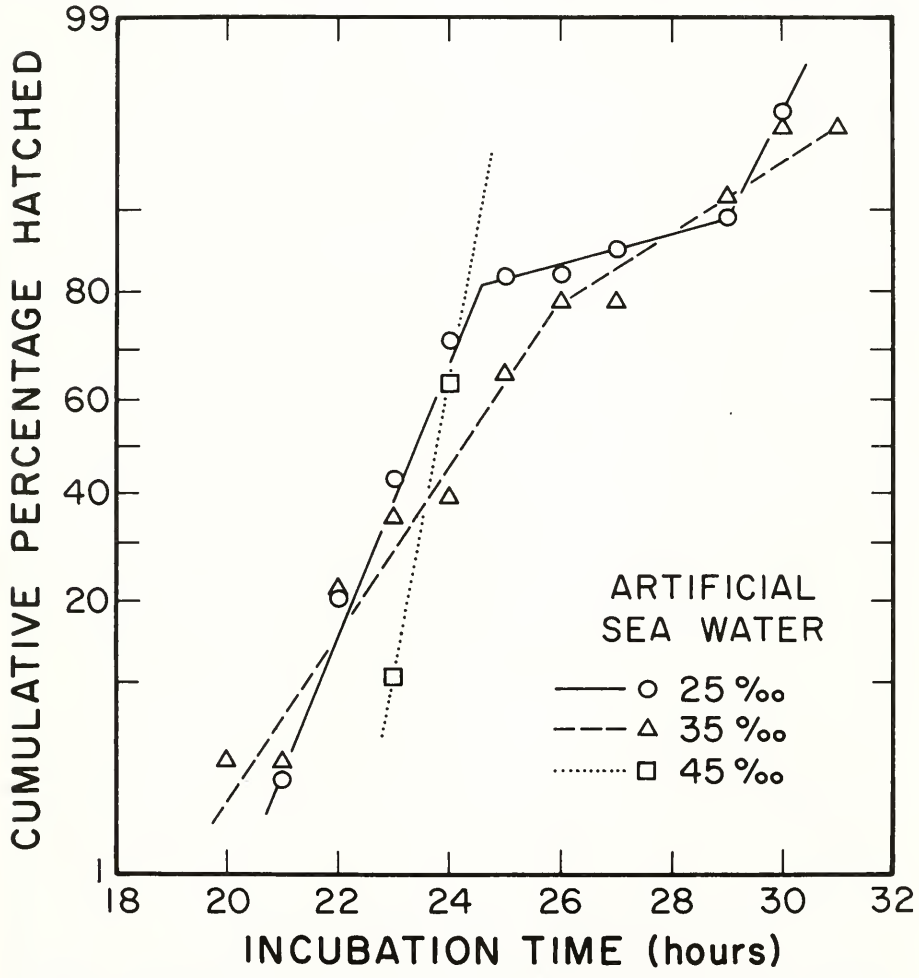

FIGURE 3. Pattern of hatching in artificial sea water of three salinities at 24 C, plotted as in Figure 2.

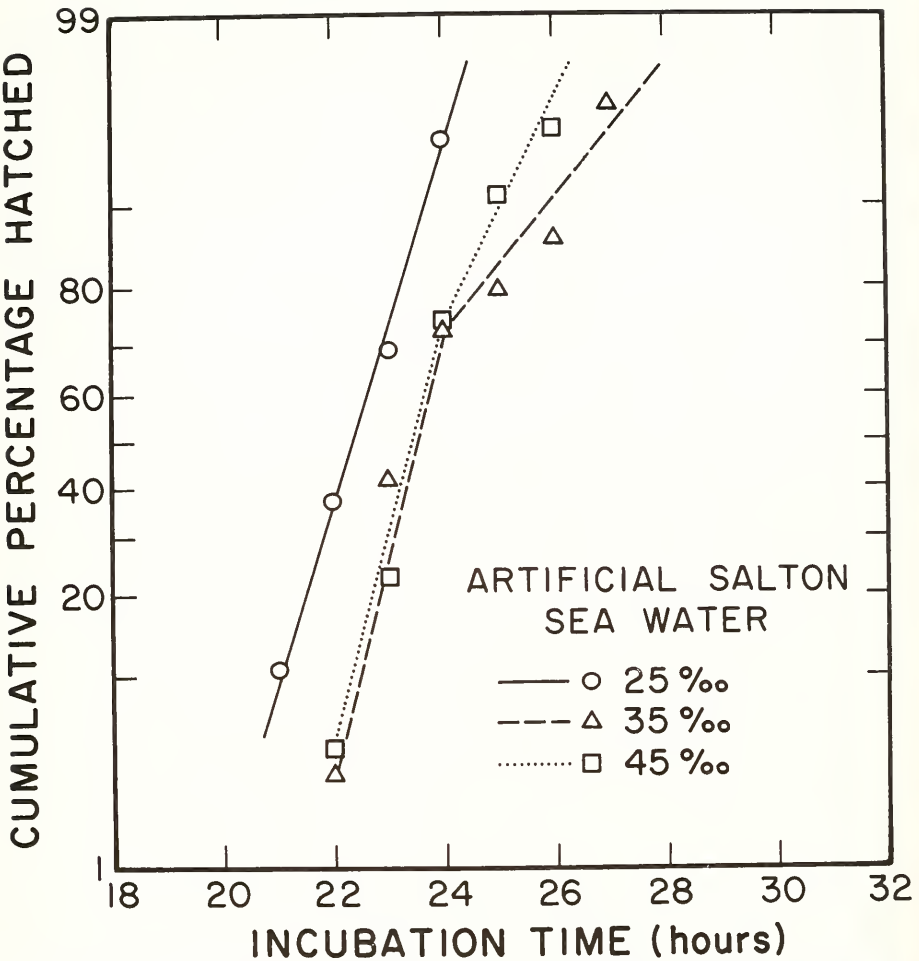

FIGURE 4. Pattern of hatching in artificial Salton Sea water of three salinities at 24 C, plotted as in Figure 2.

Some larvae displayed irreversible axial deformities at hatching (kinked or bent notochords). When these are subtracted from the total number hatched, there appear to be slightly more morphologically normal larvae in SSW (natural and artificial) than in sea water—except, again, in 25 °/₀₀ (Table 5).

The survival of hatched larvae was extremely poor in SSW (Figure 5), and no larvae survived to complete yolk absorption in artificial SSW of 35 and 45 °/₀₀. In natural SSW, approximately 6% of the larvae were alive at yolk exhaustion, which is nearly identical to the value of 5% for larvae in SSW in the first experiment. In contrast, survival to complete yolk absorption was over 90% in natural sea water and in artificial sea water of 25 °/₀₀. Larval survival declined somewhat in artificial sea water of higher salinities (Figure 5), but was 60% at complete yolk absorption, even in 45 °/₀₀.

The hatching of viable larvae, defined here as those morphologically normal and capable of surviving to yolk exhaustion, decreased with increasing salinity in artificial sea water (Table 5). In natural SSW, viable hatch was about 4%.

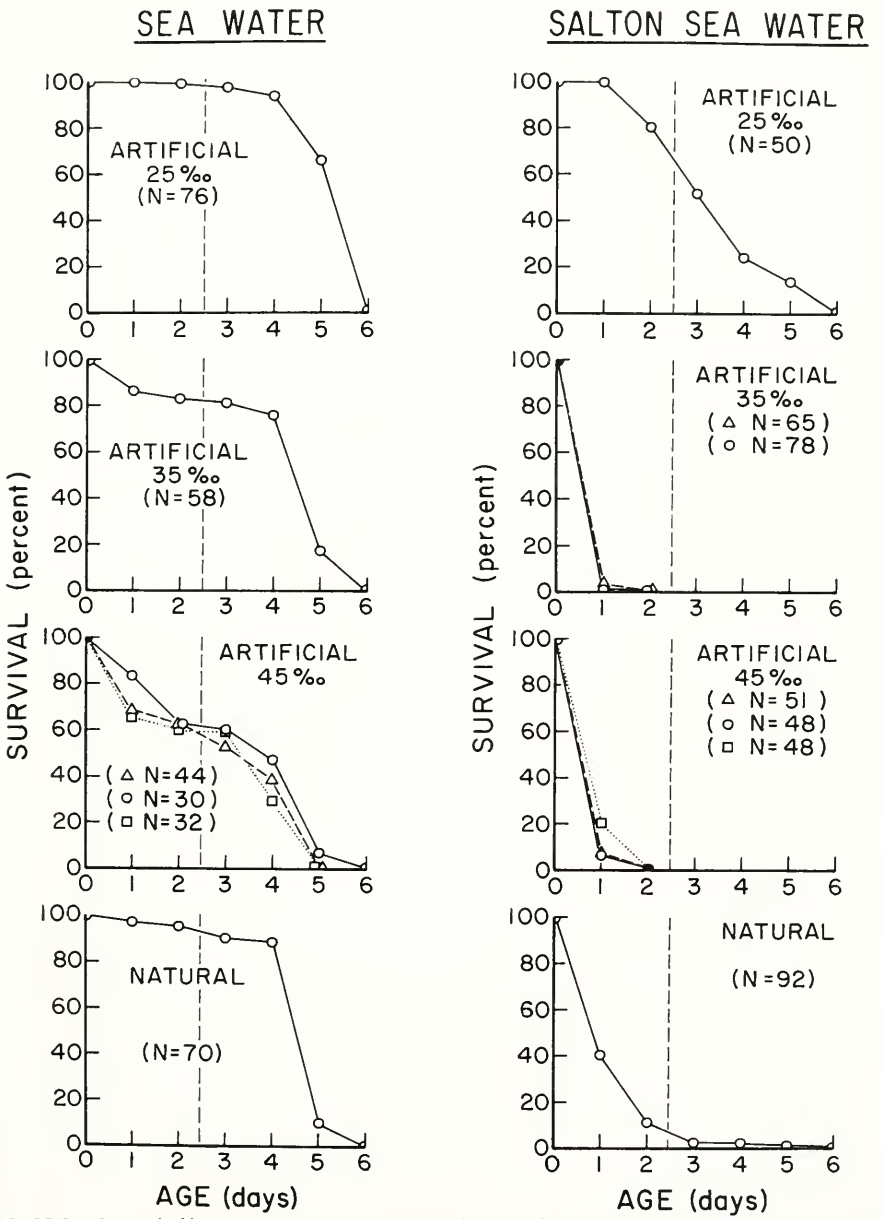

FIGURE 5. Survival of larvae in various water types in the second experiment. For some water types there were two or three replicate groups of larvae. The number of larvae in each group, N, is given in parentheses. The vertical dashed line indicates the time of complete yolk absorption at the experimental temperature of 24 C.

DISCUSSION

The current results concerning salinity tolerance of bairdiella eggs and larvae agree with those of Lasker *et al.* (1972). In SSW of 35 °/₀₀ salinity with antibiotics, 72% of eggs obtained from mature fish in the Salton Sea hatched and half of the hatched larvae died within one day after hatching (Lasker *et al.* 1972); in sea water, 82% hatched and almost all of the larvae were alive 14 hours after hatching. In 40 °/₀₀ (SSW) only 30% hatched and mortality was complete by 14 hours after hatching, while in 45 °/₀₀ (SSW) and above no larvae hatched. Unfortunately, observations in the earlier study were terminated well before complete yolk absorption, and field operations did not allow rigorous temperature control until a late stage of embryonic development. In experiments with eggs from hormone-induced spawnings, conducted at a constant 21 C (70 F), Lasker *et al.* (1972) also found poor survival in SSW, especially at the higher salinities, although again the observations were terminated early and no estimate of survival to complete yolk absorption can be made from the data. These authors noted bent tails and an inability to swim among bairdiella larvae hatching in 40 °/₀₀ (SSW) and above.

Whitney (1961*a*) described a small experiment in which he collected bairdiella eggs in plankton tows in the Salton Sea and observed them hatching in the laboratory. The larvae died the second day after hatching, much too early for starvation to be the cause. This may be another case of high early mortality occurring as a result of the inherent nature of SSW, although the exact cause of death in Whitney's experiment is impossible to determine from the published account.

In the present work, experiments conducted a year and a half apart showed similar high rates of mortality in SSW when compared with controls in sea water, and exactly the same response was noted in artificial SSW. This response therefore cannot be considered an artifact but must reflect a sensitivity of bairdiella eggs and larvae to some characteristic of water from the Salton Sea. Comparable results for eggs ovulated naturally by fish living in the Salton Sea and those induced to ovulate in the laboratory suggest further that this sensitivity is not related to the acclimation of spawning fish to ordinary sea water. The different patterns of hatching in the two types of water are additional indications of a fundamental difference between them.

Measurements show that SSW has a somewhat lower osmotic pressure than ordinary sea water of comparable salinity (Table 3), so that osmotic stress cannot be the detrimental factor in SSW. Even in the relatively low salinity of 25 °/₀₀, the survival of bairdiella eggs and larvae is poorer in SSW than in sea water. It seems reasonable to attribute the deleterious influence of water from the Salton Sea to its unusual combination of ions (Table 2). Carpelan (1961*a*) has pointed out that SSW has relatively less Mg, K, Cl, a similar proportion of Na, and more SO_4, Ca, and HCO_3 than ocean water. The most striking differences between SSW and sea water are the extremely high proportions of Ca and SO_4 in SSW. The sea water used in the present experiments contained 404 mg of Ca and 2648 mg of SO_4 per liter, whereas the SSW contained 1080 and 8300 mg/liter of these two ions, respectively. The divalent cations, in particular, are known to have pronounced physiological effects and to interact in a complex way (Heilbrunn 1952), and it should be stressed that bairdiella eggs and early larvae lack the organs associated with ion regulation in adult fish—viz., gills, kidney, and an open gut.

The large catches of sport fishermen, as well as surveys made by the California Department of Fish and Game, indicate that the bairdiella population in the Salton Sea is thriving (Robert G. Hulquist, Calif. Dept. Fish and Game, pers. comm.). How can this fish be so successful in the Salton Sea if only 5 or 6% of the larvae survive to the feeding stage in SSW, even at moderate temperatures? In the first place it should be recalled that all marine fishes which have high fecundities and produce pelagic eggs and larvae display a very high rate of mortality very early in development. This mortality often appears to occur shortly after the exhaustion of the yolk supply and has usually been attributed to starvation or predation (May 1974). Most of the marine zooplankters known to prey on fish larvae—medusae, ctenophores, chaetognaths, pelagic polychaetes—are absent in the Salton Sea (Carpelan 1961*b*). The only significant natural predators of fish, in any phase of their life cycle in the Salton Sea, are probably other fish (Quast 1961, Whitney 1961*b*). The Salton Sea is extremely productive (Federal Water Quality Administration 1970), and food is probably not a limiting factor for larval fish there. Carpelan (1961*b*) found concentrations of the rotifer, *Brachionus plicatilis,* as high as 1200 per liter (0.26 gal) in the Salton Sea in August. Neither Carpelan (1961*b*) nor Young (1970) found rotifers or copepods in the plankton during the main part of the bairdiella spawning season (April and May), but they took samples at only one or two stations, and Carpelan (1961*b,* p. 50) referred to the "apparently great local differences in the distribution of organisms in the Salton Sea." I have collected very large numbers of rotifers and copepods in the Salton Sea during April and May just a few meters from the southwestern shore. Rotifers from such collections have proved to be excellent food for larval anchovies (Theilacker and McMaster 1971) and bairdiella (May, unpublished observations) maintained in the laboratory. The few larval bairdiella I have examined from the Salton Sea contained rotifers and copepod nauplii in their guts.

From the foregoing one may infer that bairdiella larvae suffer less mortality from predation or lack of food than similar larvae in the ocean. Female bairdiella produce between 40,000 and 400,000 eggs at spawning (Whitney 1961*a,* Haydock 1971), depending on the size of the fish. This high reproductive potential must be enough to maintain the population in the face of high early mortality due to physical stress and whatever later mortality comes from predation and other sources. If, however, drastic mortality before the feeding stage is characteristic of larvae in the Salton Sea as well as in SSW in the laboratory—and there is every indication that this is the case—the situation of bairdiella in the Salton Sea may be precarious. An unfavorable change (such as decreased food supply, increased predation, or increased physical stress), even if slight, might have serious consequences for the population. High salinities of Salton Sea water will no doubt prove to be more limiting than would high salinities of ordinary sea water.

Hedgpeth (1956) points out that much of the fauna in hypersaline and relict lagoons is allochthonus. Migration from the sea accounts for the presence of many species in such areas. Only a limited number of fish species reproduce successfully in the Salton Sea. The few mullet (*Mugil cephalus*) and threadfin shad (*Dorosoma petenense*) found there are migrants from the Colorado River and do not reproduce in the Salton Sea (Hendricks 1961*a, b*). Two small fishes spawn and maintain populations along the periphery of the Sea, the mudsucker (*Gillichthys mirabilis*) and the desert pupfish (*Cyprinodon macularius*). Neither of these hardy fish

is of economic importance, although the mudsucker is used as a bait fish. Of the many species of fishes that have been introduced to the Salton Sea (Walker, Whitney, and Barlow 1961), besides the mudsucker only the sargo (*Anisotremus davidsoni*), the orangemouth corvina (*Cynoscion xanthulus*), and the bairdiella have been successful there. Relatively small numers of bairdiella, sargo, and orangemouth corvina were introduced into the Sea (67, 65, and 272 or fewer, respectively), but they eventually established huge populations. Other species, introduced in far greater numbers [e.g., 9,000 anchoveta (*Cetengraulis mysticetus*), 6,000 northern anchovy (*Engraulis mordax*), 1,700 or more shortfin corvina (*Cynoscion parvipinnis*)], apparently never reproduced successfully there (Walker, Whitney, and Barlow 1961). The ability of the early developmental stages to tolerate the chemical composition of Salton Sea water, even to a slight degree, may have dictated which species became established in the Salton Sea.

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THE VALIDITY OF OTOLITHS AS INDICATORS OF AGE OF PETRALE SOLE FROM CALIFORNIA[1]

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Otoliths from juvenile petrale sole, *Eopsetta jordani* (Lockington), caught in research vessel trawls from San Francisco and Crescent City Areas of California were used with otoliths from petrale sole less than 33 cm (13 inches) from commercial catches off San Francisco to determine their validity as age indicators. Validity of petrale sole otoliths for use in age studies is supported by seasonal formation of the different marginal zones, modes in length frequencies of immature fish that correspond to age groups, and correspondence of calculated and actual sizes of age groups. The formation of the first annulus is completed in spring over a year after spawning when calculated and observed average lengths are 10.3 cm (4.1 inches) and 11.1 cm (4.4 inches) respectively. Aging criteria are presented to assure proper year class assignment.

INTRODUCTION

Petrale sole, *Eopsetta jordani,* (Lockington), is one of the most important flatfish in the Pacific coast trawl fishery. In California, petrale sole rank third in poundage behind catches of English sole, *Parophrys vetulus,* and dover sole, *Microstomus pacificus.* Annual petrale sole landings ranged from 30 to 2,305 megagrams (Mg) (66,000 to 5,082,000 lb) between 1924 and 1961. Since 1962 petrale sole landings have been stable and averaged 1,392 Mg (3,066,000 lb).

Age composition of petrale sole in the California fishery is needed to estimate parameters for stock assessments and an age sampling program based on otoliths is in progress. Petrale sole scales are unsatisfactory for aging because they have indistinct, evenly spaced circuli. Other methods of aging petrale sole were also found inadequate.

FIGURE 1. Otolith pairs from petrale sole caught in October 1970. Top left to right ages 0, I with radius measurement (0.86 mm), and II. Bottom left to right ages III and IV. Photograph by R. J. Nitsos, August 1973.

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Petrale sole otoliths (sagittae) are large, oval, relatively thin, and have distinct opaque and translucent zones (Figure 1). They have been used for aging petrale sole by Cleaver (1949), Harry (1956), and Ketchen and Forrester (1966).

The validity of age determinations with petrale sole otoliths was established with adult or near-adult fish. Cleaver (1949) noted a similar pattern in the formation of opaque and translucent bands on otoliths of petrale sole landed at Washington ports. He also found general agreement between growth rates shown by recaptured tagged fish and growth determined from aging otoliths of female petrale sole. Ketchen and Forrester (1966) determined that otoliths provided a reasonably reliable estimation of age for petrale sole in Canadian waters by comparing deviations from mean length-frequency composition with deviations of mean age-frequency, and by comparing growth rates computed from age-length data and growth from recaptured tagged fish.

The validity of petrale sole otoliths as indicators of age in California was uncertain and because age characteristics of young fish were not determined in earlier investigations a study was initiated in 1970. The results of this study are reported herein.

METHODS AND MATERIALS

To validate petrale sole otoliths as indicators of age, we: (i) examined the character of the margins of otoliths collected throughout the year to determine the seasonality in zone formation, (ii) used length frequencies to determine modes that correspond to age groups, and (iii) compared calculated growth with actual growth.

Our age determinations, based on those of Cleaver (1949), have been the enumeration of translucent or hyaline zones (Figure 1) and for this study the hypothesis is that these are annuli.

In research vessel trawls off San Francisco, using 13 m (43 ft) headrope otter trawls with 3.2-cm (1.25-inch) mesh, 123 petrale sole 7.9 to 37.8 cm (3.1 to 14.9 inches) TL were caught between March 1970 and September 1971. In two trawls with the same gear off Crescent City, California, 60 petrale sole, 7.1 to 25.0 cm (2.8 to 9.8 inches) TL, were caught in October 1972. Fifty-nine were taken in one trawl in water 55 m (30 fm) deep.

Of the 183 petrale sole caught, 17, 40, and 53 individuals measured 6 to 10 cm (2.3 to 3.9 inches) TL, 11 to 15 cm (4.3 to 5.8 inches) TL, and 16 to 20 cm (6.2 to 7.8 inches) TL, respectively. The 183 fish were caught in several depth ranges (Table 1). Most were caught at depths between 38 to 55 m (21 to 30 fm). Fish under 15 cm (5.9 inches) TL were taken only between 38 and 73 m (21 and 40 fm).

TABLE 1. Numbers of Petrale Sole by Size Categories and Water Depths Taken off California in Research Vessel Trawls with Small Mesh Nets.

Depth zone		Total length cm							
Meters	Fathoms	6–10	11–15	16–20	21–25	26–30	31–35	≥36	Total
38–55	21–30	16	31	27	37	5			116
57–73	31–40	1	9	20	6	2			38
75–91	41–50			5	6	6	7	1	25
>91	>50			1		3			4
Totals		17	40	53	49	16	7	1	183

In addition to petrale sole taken by research vessels, 291 caught by commercial trawlers in the Gulf of the Farallones in 1969 and 1970 were used in the study. These fish were "medium" petrale sole, the market category for petrale sole that are less than 33 cm (13 inches) TL.

Each fish used in the study was measured and the total length in millimeters was recorded. The sex of each fish was determined and both otoliths (sagittae) were removed for study. Otoliths from fish from the above-mentioned sources were examined while immersed in 95% ethyl alcohol under a dissecting microscope with reflected light at 10 to 30 diameters of magnification. The alleged annuli were counted and the condition of the margin was noted.

For growth comparisons, otoliths from 110 of the 123 petrale sole taken in research vessel trawls off San Francisco were measured with an occular micrometer. The distances from the center of the left otolith to alleged annuli and to the ventral margin were measured along the transverse axis (Figure 1).

RESULTS

Otolith Margin Condition

Examination of the margins of otoliths from 379 petrale sole revealed four general classifications of condition. One class was narrow hyaline; the otolith margin has a hyaline zone which is markedly thinner than completed hyaline zones within the margin. Wide hyaline margins were as wide as the completed ones but no significant amounts of opaque material were observed on the outer margin. Narrow opaque margins were markedly thinner than completed opaque zones within the margin. Wide opaque margins were as wide as the completed ones but no significant amount of hyaline material was observed on the margins.

Margins of otoliths were either narrow or wide hyaline in November. In December, the majority (72%) had wide hyaline zones. Opaque zones first appeared on otolith margins in April when the majority of opaque zones were narrow. The proportion of narrow opaque zones increased through June and then declined. Concurrently, an increase occurred in wide opaque zone frequency that continued through August and declined thereafter. From these observations the majority of hyaline zones appear to be completed by June (Table 2, Figure 2).

TABLE 2. **Composition of Petrale Sole Otolith Marginal Zones by Number and Percent, March-October 1970.**

	Opaque narrow no. (%)	Opaque wide no. (%)	Total opaque no. (%)	Hyaline narrow no. (%)	Hyaline wide no. (%)	Total hyaline no. (%)
1969 November	----------	----------	----------	8 (32)	17 (68)	25 (100)
December	----------	----------	----------	7 (28)	18 (72)	25 (100)
1970 March	----------	----------	----------	11 (35)	20 (65)	31 (100)
April	8 (32)	3 (12)	11 (44)	1 (4)	13 (52)	14 (56)
June	18 (37)	11 (22)	29 (59)	----------	20 (41)	20 (41)
July	8 (32)	11 (44)	19 (76)	----------	6 (24)	6 (24)
August	4 (8)	35 (72)	39 (80)	6 (12)	4 (8)	10 (20)
September	8 (14)	28 (50)	36 (64)	20 (36)	----------	20 (36)
October	2 (2)	37 (43)	39 (45)	46 (53)	9 (2)	55 (55)
Totals	----------	----------	173	----------	----------	206

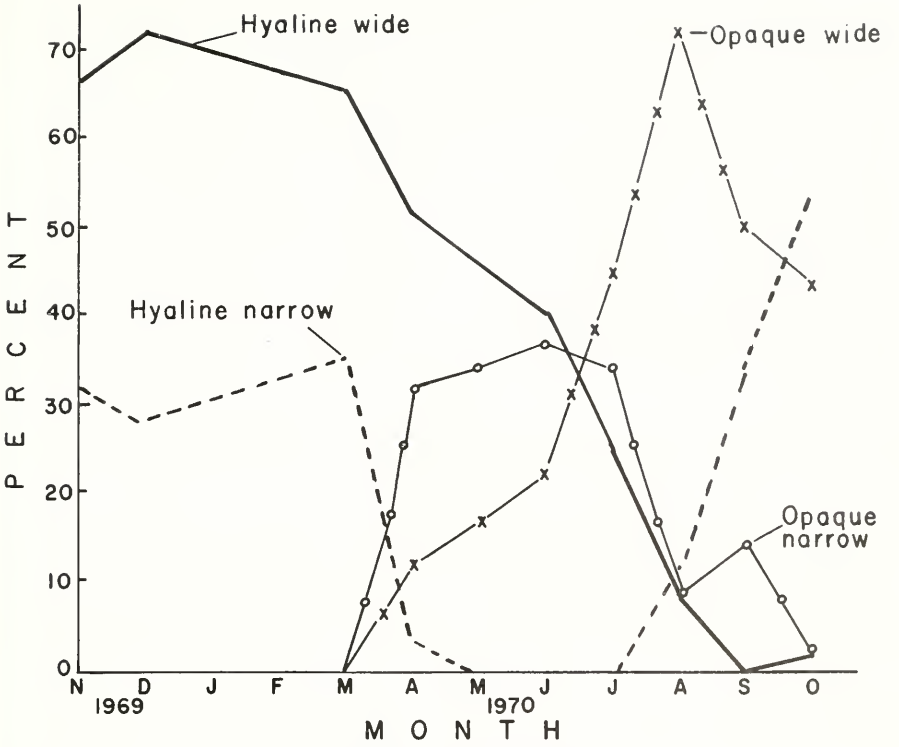

FIGURE 2. Percent frequency of occurrence of otolith margin types on otoliths from 370 petrale sole collected from the Gulf of the Farallones, November 1969 to October 1970.

Our studies thus show that seasonal variability in occurrence of opaque or hyaline zones exists since we observed only hyaline zones on otolith margins from November through March (Table 2, Figure 3). Hyaline zones decline thereafter to 20% in August. Opaque zones first occur in April, reach a peak of 80% in August and decline thereafter.

A deviation from the expected occurrence of wide hyaline zones throughout the year exists in our observations. In early summer, percentages of wide hyaline zones should decline rapidly and be replaced by narrow zones. This was not the case, as wide hyaline zones persisted through August. The cause for this might be that all the otoliths that were judged to have wide hyaline zones in June, July, and August were from petrale sole taken in commercial catches. These fish ranged in age from 4 to 7 years and in fish older than 4 or 5 years it is difficult to discern the narrow opaque zone due to crowding of zones at the otolith margin.

Length Frequencies and Sizes of Aged Petrale Sole

Research vessel catches of young petrale off San Francisco (123 fish) were less than expected. However, a prominent modal group occurs in length frequencies of petrale sole for several collections during several months that coincides with length modes of age groups based on otolith readings. Collections during March have a mode at 16 cm (6.3 inches) and age II fish have a modal length of 16 cm and an average length of 16.5 cm

(6.5 inches). In August a mode occurs at 20 cm (7.9 inches) which is the same modal length of age II fish; the mean length of age II fish is 20.8 cm (8.2 inches). The length frequency for September 1971 has a mode at 13 cm (5.1 inches); this modal group consists entirely of age I fish (Figure 4).

A progression occurs for length modes of the predominant age group II fish. In March 1970 the modal length is 16 cm (6.3 inches) and it increases to 20 cm (7.9 inches) in August. The following February the mode is 26 cm (10.2 inches) when the fish are age III. Progressions of the 0 to I and I to II age groups are also suggested by the few fish collected in October 1970, February 1971, and September 1971 (Figure 4).

The length frequency distribution for the 60 petrale sole taken in October 1972 off Crescent City displays two prominent modes at 10 and 19 cm (3.9 and 7.5 inches). These modes coincide with the modal lengths of ages I and II based on age readings of otoliths (Figure 5).

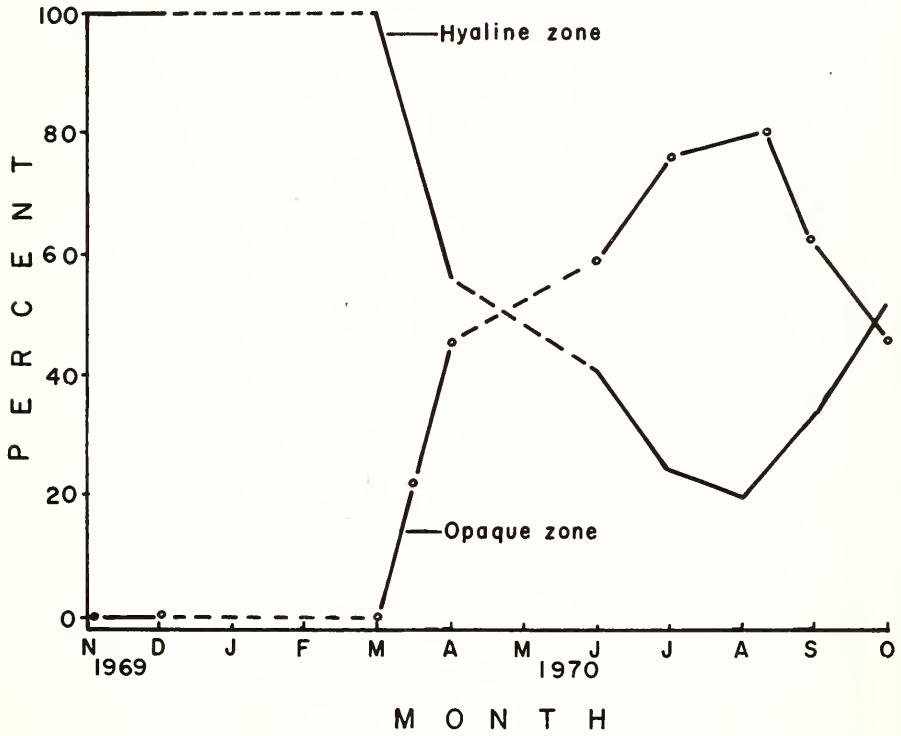

FIGURE 3. Percent frequency of occurrence of hyaline and opaque margin zones on otoliths from 379 petrale sole collected from the Gulf of the Farallones, November 1969 to October 1970.

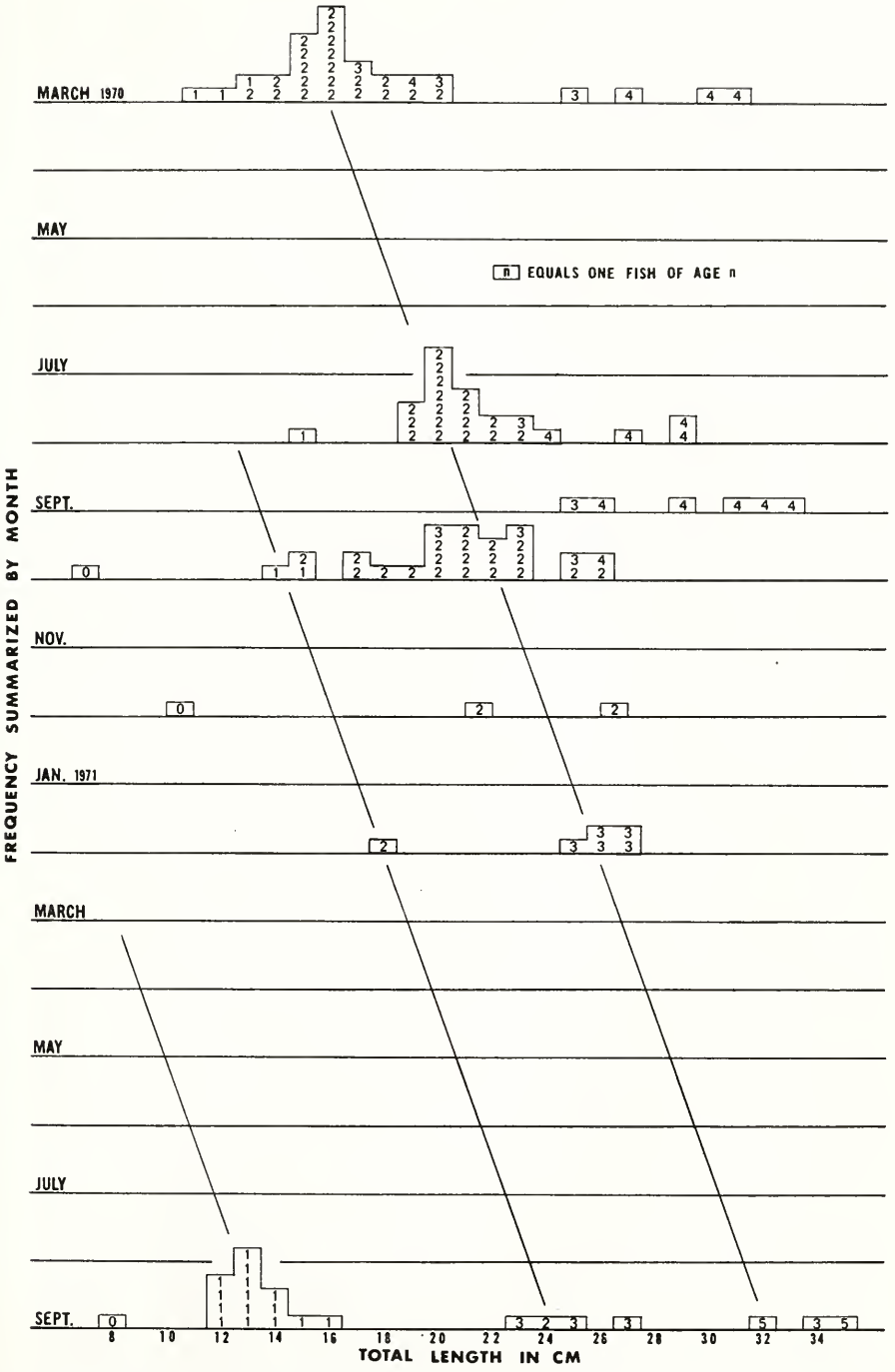

FIGURE 4. Length frequency histograms of petrale sole from the Gulf of the Farallones, March 1970 to September 1971. Numbers in histograms indicate age from otoliths of each respective fish.

Calculated and Actual Growth Comparison

The relationship between otolith radius and total length of respective fish was examined and a plot of points suggested a linear relationship. A regression of the otolith radii on total lengths by the method of least squares gives the relationship

$$Y = -4.3347 + 16.7553X$$

that has a correlation coefficient of 0.92. Y is the total length in cm and X is the total otolith radius in mm.

Fish total lengths for ages I, II, III, and IV were calculated by using the mean radii measurements of alleged annuli in the above equation. Mean otolith radii for completed ages I, II, III, and IV are 0.88 mm (0.03 inch), 1.30 mm (0.05 inch), 1.58 mm (0.06 inch), and 1.76 mm (0.07 inch) respectively. Calculated mean total lengths for these ages are 10.3 cm (4.1 inches), 17.4 cm (6.8 inches), 22.1 cm (8.7 inches), and 25.1 cm (9.9 inches) respectively (Table 3). Lengths of aged petrale sole captured in late fall and winter were used for comparison because these time periods are near the completion of the petrale sole growth year. Observed mean total lengths for ages I through IV are 11.1 cm (4.3 inches), 16.6 cm (6.5 inches), 21.6 cm (8.5 inches), and 26.6 cm (10.4 inches) respectively. These observed mean total lengths correspond closely with the calculated lengths; the differences are less than 1.0 cm (0.4 inch) for ages I through III and for age IV the difference is 1.5 cm (0.6 inch).

The null hypothesis that the calculated and observed means of each year class were equal was tested with the "Students t" test. The resulting "t" values were 1.60, 1.97, 0.77, and 1.55 respectively. These values do not exceed "t" values with P = 0.05 for any of the ages so each difference is not significant.

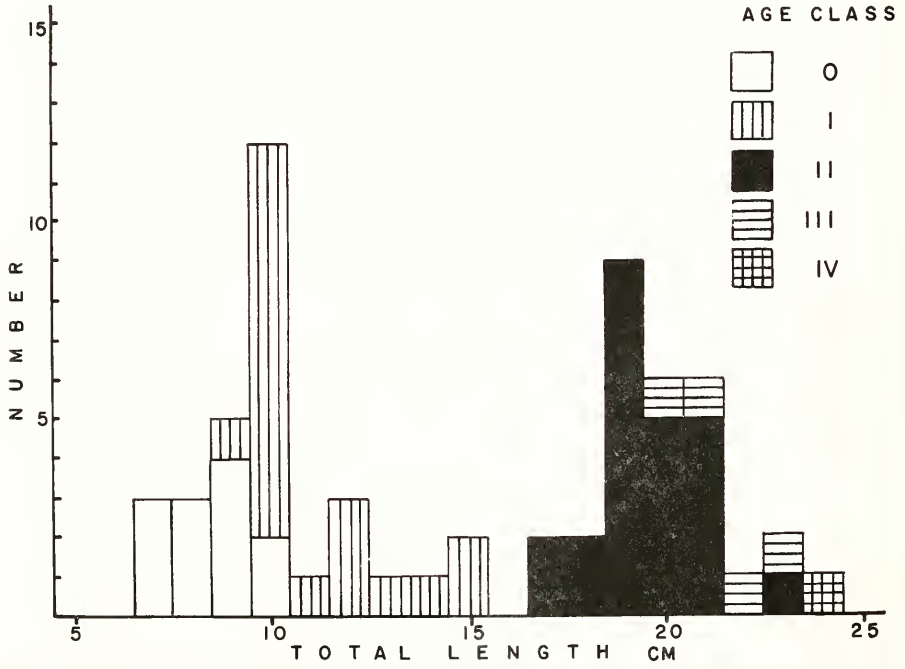

FIGURE 5. Length frequency histogram of petrale sole collected off Crescent City, California, October 1972.

TABLE 3. **Petrale Sole Otolith Measurements of Radii of Hyaline Zones, Calculated Total Lengths* and Observed Total Lengths for Ages I-IV.**

Age completed	Number of measurements	Mean radius mm	Range of radii mm	Calculated mean TL cm	Estimate of standard deviation	Range of calculated TL mm	Number of observed TL	Observed mean TL cm	Estimate of standard deviation	Range of observed TL mm
I	110	0.877	0.71–1.05	10.3	1.04	7.6–13.2	5	11.1	2.15	7.9–13.6
II	89	1.298	0.95–1.48	17.4	1.83	11.6–20.5	25	16.6	1.63	14.1–20.3
III	28	1.578	1.14–1.76	22.1	1.57	14.8–25.2	27	21.6	3.04	15.4–27.8
IV	16	1.756	1.52–2.05	25.1	1.61	21.1–30.0	10	26.6	3.42	19.0–31.2

* $Y = -4.3347 + 16.7553X$ where Y = calculated length; X = otolith radius.

DISCUSSION

Formation of First Annulus

Petrale sole spawning occurs off California mainly in December, January and February in 329 to 411 m (180 to 225 fm) off Point Sal, Point Montara, Point Delgada and Cape Mendocino.

Petrale sole eggs are pelagic and under various laboratory conditions they hatch in 6.2 to 13.5 days at which time the larvae are 2.85 mm (0.11 inch) long; 10 to 16.5 days after hatching when yolk exhaustion occurs the larvae are 5.5 to 5.7 mm (ca. 0.22 inch) (Alderdice and Forrester 1971). No petrale sole larvae have thus far been identified in nature (Forrester 1969). The smallest petrale sole taken were 21 and 22 mm (0.83 and 0.87 inch) TL fish caught in midwater off northern California in April (Porter 1964).

Young petrale sole are available to bottom trawls in summer and fall. Thirteen petrale sole 8 to 9 cm (3.1 to 3.5 inches) were trawled from 18 to 90 m (10 to 49 fm) depths off British Columbia between May and August (Ketchen and Forrester 1966). In our study, petrale sole 7.9 and 8.3 cm (3.1 and 3.3 inches) were caught in trawls in September–October off San Francisco and 11 individuals 7.1 to 10 cm (3.0 to 3.9 inches) were trawled in October from northern California waters. All but one of these 13 fish were in their first year of growth (0 age class). Otoliths from these fish exhibited narrow hyaline bands forming at their margins. These hyaline zones are expected to broaden in winter and thereafter form the first annulus. In the previous section on growth histories we found that at completion of the first annulus, the lateral otolith radius averaged 0.88 mm (0.03 inch) and the calculated average length of age I fish was 10.3 cm (4.1 inches). Observed lengths of five age I petrale sole averaged 11.1 cm (4.4 inches).

Definition of Annulus

We cannot define a petrale sole otolith annulus as rigidly as done by Fitch (1951) and Chugunova (1959) for other species. They defined an annulus as the interface between the hyaline zone and outer opaque zone. With petrale sole there is an extended period when some otoliths have hyaline zones on margins, and crowding of marginal zones on otoliths of older fish renders the interfaces near margins indistinguishable. In the former case with a petrale sole spawned in one winter, the annulus would not be completely formed with an outer opaque zone, conceivably, until

June, 18 months later. If sampled at about 17 months later in May, using the interface definition, this fish would be assigned incorrectly to the 0 age group; from July to December it would be placed correctly in the I age group; in January to May of the following year it would again be misplaced in age group I. For this reason we give petrale sole an arbitrary birth date of January 1 and all hyaline margins from January 1 to September 1, regardless of presence or absence of an adjoining outer opaque zone, are considered annuli; those from September 1 to December 31 are not considered annuli.

SUMMARY

The hypothesis that hyaline zones are annuli is supported by: (i) the seasonality in the formation of hyaline and opaque zones, (ii) the occurrence of single modes and two distinct modes in length frequencies of young fish in collections, and (iii) agreement of calculated lengths with observed lengths of age classes of young fish.

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DISTRIBUTION, HARVEST AND SURVIVAL OF AMERICAN WIGEON BANDED IN CALIFORNIA [1]

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Population distribution, sex ratio, kill rate and survival were determined from 32,097 American wigeon banded in California from 1951 to 1969. There are two wigeon populations that winter in California; one is in the Central Valley and the other in the Imperial Valley. The Sacramento Valley is the main wintering area in California. Since 1971 a marked decrease has occurred in wigeon wintering in the Imperial Valley with an increase in Mexico. The true sex ratio of wigeons in the Sacramento Valley is probably close to the 55.0% males found in hunter bag checks and the 56.4% males found in the trapped sample. The male has a higher band recovery rate and survival rate than the female. The mean recovery rate for adult male wigeons banded on the Gray Lodge Wildlife Area is 4.42 ± 0.23% and the mean survival rate is 66.04 ± 1.65% as compared to the Gray Lodge female recovery rate of 3.26 ± 0.28% and the mean survival rate of 58.24 ± 3.63%. The mean life span for adult males is 2.32 years and 1.66 years for adult females.

INTRODUCTION

The American wigeon (*Anas americana*) nests across much of Canada and Alaska and winters in all four North American flyways. This report analyzes wigeon band recoveries from birds banded in California. The objective was to increase our knowledge of migration patterns, survival rates and population turnover, and thus provide a more sound basis for management of this species.

From 1951 through 1971 the California Department of Fish and Game banded, or assisted in banding, 32,097 wigeon during the posthunting season period. Of these, 11,576 were banded on the Gray Lodge Wildlife Area in the Sacramento Valley, 566 on the Grasslands of the San Joaquin Valley and 19,955 on the Wister Wildlife Area and the Salton Sea National Wildlife Refuge in the Imperial Valley. Except for the years 1968, 1969 and 1970 wigeon banding on Gray Lodge has been continuous since 1953. On the Grasslands area wigeon trapping and banding were conducted only during 1955, 1956 and 1958. In the Imperial Valley the banding has been continuous since 1951 except that in 1962 an adequate sample was not obtained. Every year an attempt was made on each area to band at least 1,000 wigeon, but was not always successful. Formerly stationary wire bait traps were utilized to catch the ducks. More recently, cannon nets proved more efficient in trapping wigeon.

METHODS

Seber's (1970) model for band recovery analysis was used to estimate band recovery rate, survival rate and life span of wigeons wintering in California. The method can be used where survival rates, band reporting rates and hunting pressure vary from year to year. All birds alive in a given year, regardless of when they were banded, are assumed to have similar

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hunting pressure and band reporting rates in that year. Only data from adult birds is used with this method. The method assumes survival and recovery rates are independent of the age of the mature bird. The data were analyzed using a Fortran program (Anderson, et al., 1974) on an IBM 360/65 computer. Computer summaries of the recovery data by sex and banding area were supplied by the U. S. Fish and Wildlife Service, Laurel, Maryland.

During the years 1968–1970 insufficient samples of wigeon were banded on Gray Lodge and, therefore, the period 1953 through 1967 was used in the analyses. Only a few wigeon were banded during 1962 in Imperial Valley, and therefore the data were divided into the two periods of 1951–1961 and 1963–1969 and analyzed separately. The San Joaquin Valley data were not used in determining recovery rates and survival rates due to insufficient samples. Only bands recovered from birds shot or found dead during the hunting seasons of September 1 to February 1 were used in determining the kill rate.

RESULTS AND DISCUSSION

Migration

The Pacific Flyway has more wigeon than any other flyway and California winters most of the wigeon in the flyway. Over 50% of the wigeon harvest in the United States is concentrated in the Pacific Flyway and about 25% of this occurs in California (Geis and Cooch 1972). The annual winter waterfowl survey shows that on the average, the California wigeon population is nearly 750,000. Wigeon generally ranks second to the pintail (*Anas acuta*) as the most numerous duck in California. In some years it is replaced by the mallard (*Anas platyrhynchos*) as the second most numerous duck in the population.

There are two wigeon populations wintering in California. The larger of the two occurs in northern California, mostly in the Sacramento and San Joaquin valleys (Central Valley). The smaller population is in the Imperial Valley of southern California.

Those wigeons wintering in northern California nest in Alberta, British Columbia, the western part of the Northwest Territories and central Alaska to the Bering Sea. Few nest in the Pacific Flyway states. Their southern fall migration is mainly through Washington, Idaho, and Oregon to the Central Valley of California. A segment of the population migrates offshore from Alaska to California and winters on the bays of California. However, some wigeon of the Pacific Flyway spend the winter in Washington and Oregon. In fact, the wigeon is second on Washington's winter waterfowl inventory.

California wigeon migrate later than the pintails (*Anas acuta*) but not as late as the canvasback (*Aythya valisineria*). They do not appear in appreciable numbers on the wintering grounds until after the hunting season starts in mid-October.

It was noted that 83.8% of the band recoveries of male wigeon banded in the Sacramento Valley were recovered in California, whereas only 70% of the females were recovered in the same area. The data are consistent in that band recoveries from Washington, Idaho and Oregon revealed a high percentage of females. This could indicate that the females take a more leisurely trip to the wintering grounds than the males and therefore are more vulnerable to hunting en route. Except for a slightly higher

harvest of females in October which accounts for the larger number of females in the bag in states north of California, the monthly distribution of harvest for males and females is quite similar (Figure 1).

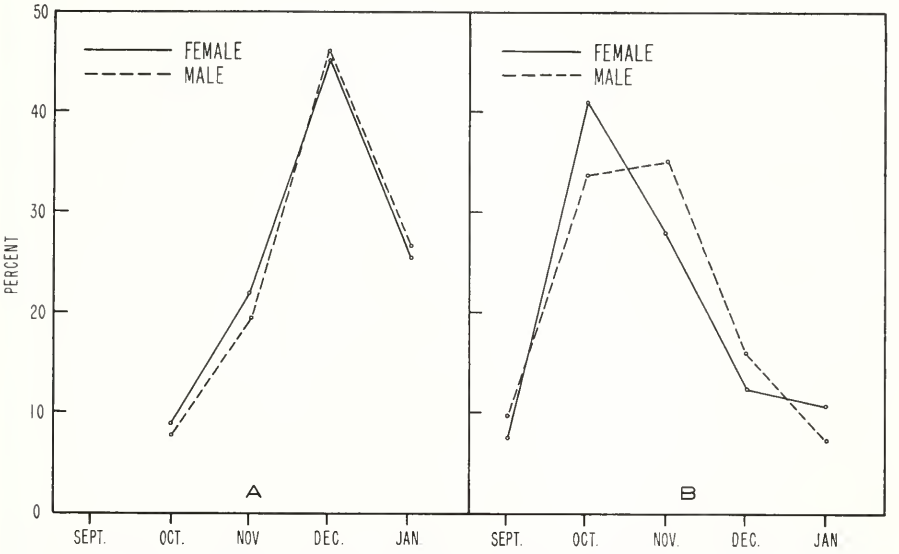

FIGURE 1. The chronological harvest of male and female wigeon banded on Gray Lodge Wildlife Area. A=recoveries in California, B=recoveries outside California.

Studies have shown that for many species, e.g., mallard, gadwall (*Anas strepera*), pintail, green-winged teal (*Anas crecca*), shoveler (*Anas clypeata*) and canvasback, the hunter bag in Canada contains more females than males. This results from the departure of many adult males prior to the opening of the hunting season (Bellrose, et al., 1961). The wigeon follows a similar pattern. Data from California banded wigeon indicate that the females have a significantly higher band recovery rate in Alaska and Canada than the males (7.9% versus 3.0%).

No females were recovered south of the San Joaquin Valley, whereas 2.8% of the males were recovered along the southern California coast and in the Imperial Valley.

The Sacramento Valley is the main wintering ground in California with 54.9% recoveries of wigeons banded on Gray Lodge recovered in the valley in later years. The Sacramento-San Joaquin River Delta with 9.1% and the San Joaquin Valley with 9.6% are also important wigeon wintering areas. Another indication of the value of the Sacramento Valley as a wigeon wintering area is that of those ducks banded in San Joaquin Valley, 32% of the band returns were recovered in the Sacramento Valley in later years. Harold McKinnie concluded in his study on wigeon of California (unpublished report, California Department of Fish and Game) that wigeon wintering in the Sacramento and San Joaquin valleys appear to be the same migratory population with the San Joaquin Valley as the southern boundary of their wintering grounds.

The wigeon population wintering in the Imperial Valley nests in the same general areas, except for a slight shift to the east, compared to those which winter in the Sacramento Valley. There are fewer Imperial Valley birds nesting in British Columbia and more nesting in Saskatchewan than those of the Sacramento Valley populations. Lensink (1964) states that

most wigeons from Alaska, British Columbia and Alberta that were shot in the United States were harvested in the Pacific Flyway, while those from Saskatchewan were recovered nearly equally from hunters in the Mississippi, Central and Pacific flyways. The migration to the Imperial Valley is also slightly more oriented toward the east than that of the Sacramento wigeon populations. There seem to be two main comparisons of the two populations (Figures 2 and 3). First, the Imperial wigeon population is more prone to scatter than the Sacramento wigeon population. Approximately 10% of the band returns from the Imperial Valley population are recovered on the wintering grounds of northern California, whereas less than 2% of the northern California population band returns

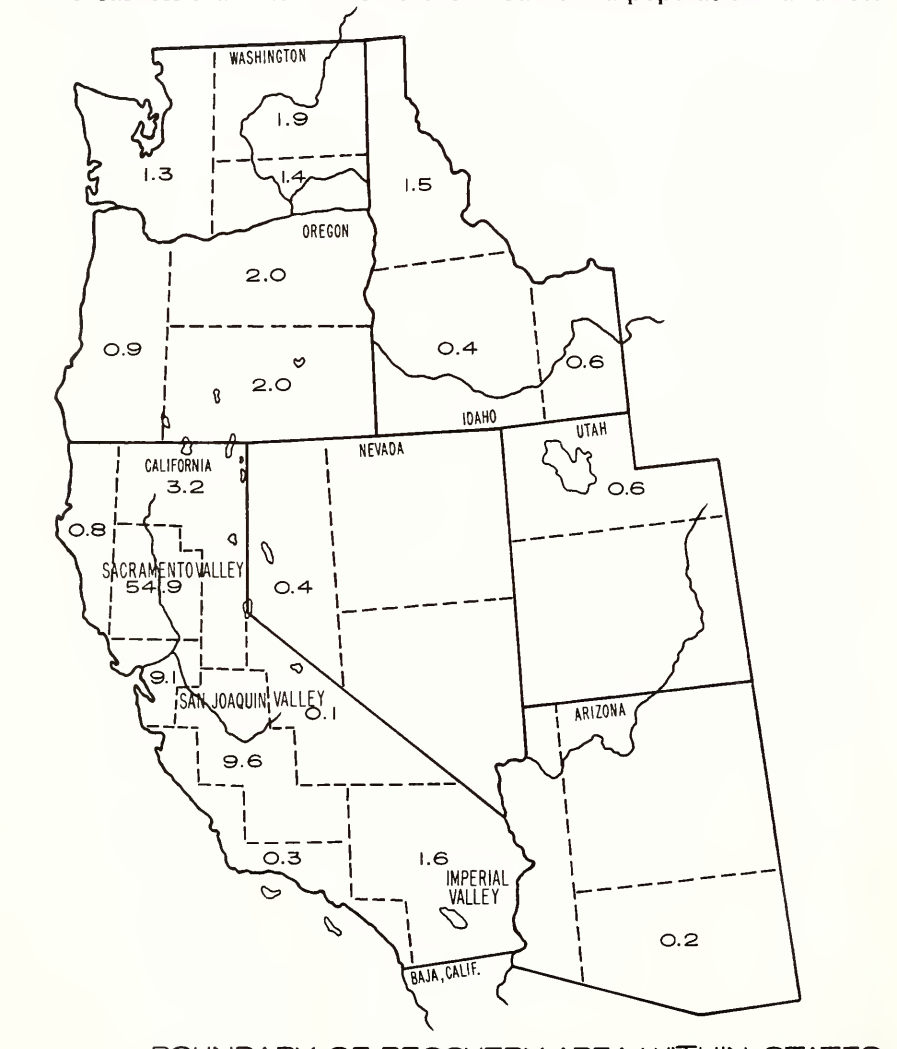

FIGURE 2. Band recoveries, by percentage, of 1,183 wigeon banded in the Sacramento Valley 1953–67 and 1971. Additional returns were from Alaska 0.5, Northwest Ter. 0.5, British Columbia 2.2, Alberta 2.5, Saskatchewan 0.5, Montana 0.9 and Tennessee 0.1.

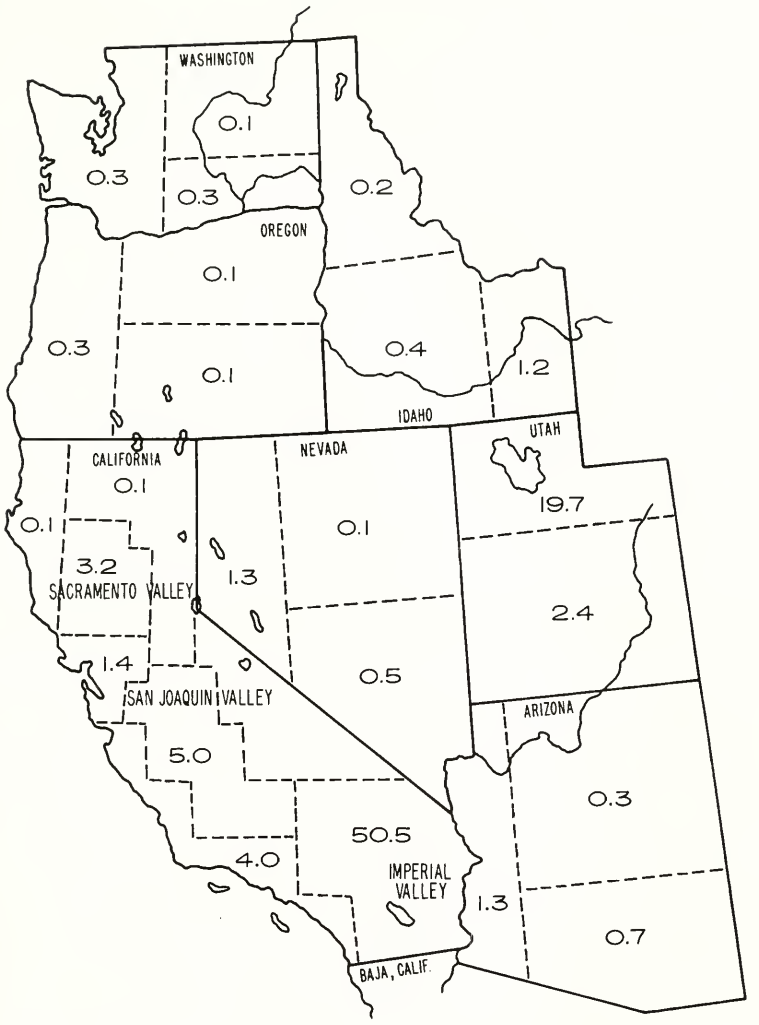

FIGURE 3. Band recoveries, by percentage, of 2,208 wigeon banded in Imperial Valley 1951–69. Additional returns were from Alaska 0.4, Northwest Ter. 0.1, British Columbia 0.5, Alberta 1.7, Saskatchewan 0.5, Montana 0.7, Wyoming 0.2, Colorado 0.1, New Mexico 0.1, Texas 0.1, Lousiana 0.1, Iowa 0.1, Kansas 0.1, Baja Calif. 1.2, Sonora 0.5 and Chihuahua 0.2.

are recovered in southern California. This trend was also found in the lesser snow goose (*Anser caerulescens hyperborea*) (Rienecker 1965) and is probably typical of all species of waterfowl using these two areas. Secondly, Utah, especially in the vicinity of the Great Salt Lake, is the most important recovery area with 22.1% of the band recoveries from the Imperial Valley wigeon population from outside of the Imperial Valley. Only 0.6% of the band recoveries from wigeon banded in the Sacramento Valley were recovered in this same area. The annual winter waterfowl inventories indicate that Utah winters very few wigeon, usually less than 2,000. Therefore, the assumption might be made that they stay in the area until inclement weather forces them to continue their migration south-

ward to the Imperial Valley or Mexico. Limited recoveries from wigeon banded preseason in Colorado (Ryder 1955) suggest that they migrate southwestward from Colorado into southern California and Mexico. This is also indicated by the Imperial Valley banded wigeons although the returns from Colorado amounted to only two bands or 0.1%.

The annual winter waterfowl inventory has shown that since 1971 a marked decrease has occurred in the number of wigeon wintering in the Imperial Valley and an increase in Mexico. From 1961 through 1970 the wigeon population wintering in the Imperial Valley averaged 21,500 birds. From 1971 through 1973 the average had a drastic drop to 5,200 wigeons; and in 1974, the most recent survey, the population dropped to a low of 1,700 wintering in the Imperial Valley. During this same 10-year period of 1961 through 1970 the wigeon population wintering on the west coast of Mexico average 48,200 birds. From 1971 through 1973 the average increased to 54,500. This population shift of wintering grounds has affected all species of ducks wintering on these areas. However, it has become most obvious in the wigeon population.

Much of this population shift probably can be attributed to increased habitat due to development of farm irrigation in Mexico during recent years. Less harrassment from hunters in Mexico could be another reason for the shift.

Few band recoveries during the spring migration made it extremely difficult to follow migration patterns to the breeding grounds. However, there is no reason to believe, from the limited data available, that there is any difference between the spring and fall migration routes.

Sex Ratios

The sex ratio of trapped samples of wigeon wintering in the Imperial Valley had more males at 70.0% than samples obtained in the Sacramento Valley at 56.4% or the San Joaquin Valley at 62.0%.

Since the trapping methods were presumably identical on all areas, if there was a bias in trapping with regard to sex, the degree of bias would be similar with all trapping stations. Thus, the sex ratio of the trapped sample would not necessarily be an indication of the true sex ratio of the whole population. A general consensus among waterfowl biologists is that there is a trapping bias towards males, especially with baited wire traps.

By comparing hunter bag check data with trapping data by area and by year (Table 1) it became clear that the sex ratio of 70% males in the trapped sample of wigeons in the Imperial Valley was not indicative of the total population. A theory is that, although the sex ratio of the hunter bag is nearer to that of the population, bag checks can also be biased towards one sex, usually males. The percentage of males in the hunter bag is similar for all areas, i.e., Sacramento Valley 55.0%, San Joaquin Valley 52.9% and Imperial Valley 57.2% (Table 1).

Note also that the percentage of males in the hunter bag and in the trapped sample for the Sacramento Valley are very similar (55.0% and 56.4%). These figures in all probability are close to the true sex ratio of the untrapped population in the Sacramento Valley but not at the Imperial Valley.

The yearly sex ratios for the trapped samples on all three areas are reasonably close to the average for each area (Table 1) which implies that whatever the cause for this unbalanced sex ratio in trapped birds, it seems to remain constant for each area. This unbalanced sex ratio is also true of green-winged teal wintering in the Imperial Valley. Moisan, et al., (1967) pointed out a preponderance of 73% male green-winged teal in the trapped samples from Imperial Valley, whereas those samples trapped in the Central Valley contained 63.8% males.

TABLE 1. A Summary of Sex Ratios of Wigeons in the Hunter Bag as Compared with Sex Ratios of Wigeons Trapped and Banded Post-season.

Year	Sacramento Valley						San Joaquin Valley						Imperial Valley					
	Hunter bag			Trapped and banded			Hunter bag			Trapped and banded			Hunter bag			Trapped and banded		
		Percent			Percent			Percent			Percent			Percent			Percent	
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
1951	--	--	--	--	--	--	--	--	--	--	--	--	749	53.3	46.7	195	63.1	36.9
1952	--	--	--	--	--	--	--	--	--	--	--	--	1672	51.6	48.4	1590	63.3	36.7
1953	--	--	--	--	--	--	--	--	--	--	--	--	529	55.2	44.8	3007	70.4	29.6
1954	2389	57.0	43.0	1087	57.3	42.7	--	--	--	--	--	--	700	61.6	38.4	1195	77.1	22.9
1955	1852	52.0	48.0	312	61.5	38.5	726	51.2	48.8	271	59.4	40.6	1983	60.1	39.9	2017	76.8	23.2
1956	7592	53.4	46.6	1059	55.3	44.7	948	56.8	43.2	135	65.2	34.8	1571	61.1	38.9	939	72.5	27.5
1957	5057	54.2	45.8	296	46.6	53.4	--	--	--	--	--	--	783	57.5	42.5	1202	71.8	28.2
1958	8104	52.9	47.1	616	58.3	41.7	1114	50.8	49.2	160	63.8	36.2	641	49.6	50.4	1382	73.8	26.2
1959	4497	52.3	47.7	600	59.0	41.0	--	--	--	--	--	--	445	60.4	39.6	300	66.7	33.3
1960	4949	58.0	42.0	1110	53.1	46.9	--	--	--	--	--	--	835	56.6	43.4	698	66.6	33.4
1961	4989	60.3	39.7	1007	53.5	46.5	--	--	--	--	--	--	376	58.5	41.5	1000	74.6	25.4
1962	1857	58.6	41.4	1022	54.4	45.6	--	--	--	--	--	--	--	--	--	--	--	--
1963	3061	61.6	38.4	1029	57.8	42.2	--	--	--	--	--	--	344	53.2	46.8	1000	62.5	37.5
1964	2154	49.6	50.4	483	63.1	36.9	--	--	--	--	--	--	391	63.9	36.1	1000	70.0	30.0
1965	2602	54.8	45.2	232	62.5	37.5	--	--	--	--	--	--	458	55.7	44.3	432	74.1	25.9
1966	2922	51.9	48.1	1022	59.7	40.3	--	--	--	--	--	--	479	55.1	44.9	1000	70.1	29.9
1967	5122	51.9	48.1	701	59.3	40.7	--	--	--	--	--	--	845	57.8	42.2	999	70.6	29.4
1968	--	--	--	--	--	--	--	--	--	--	--	--	540	56.3	43.7	1000	60.9	39.1
1969	--	--	--	--	--	--	--	--	--	--	--	--	710	60.1	39.9	999	62.3	37.7
1970	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1971	6164	57.4	42.6	1000	52.0	48.0	--	--	--	--	--	--	--	--	--	--	--	--
Total	63,311	--	--	11,576	--	--	2788	--	--	566	--	--	14,051	--	--	19,955	--	--
Mean	--	55.0	45.0	--	56.4	43.6	--	52.9	47.1	--	62.0	38.0	--	57.2	42.8	--	70.0	30.0

Harvest and Survival

California hunters rank the wigeon third in popularity, behind the favored mallard and pintail. Size of a bird and its table qualities determine rank. However, availability is probably more important than popularity in determining hunter bag composition. A hunter might prefer a limit of mallards or pintails, but if these are scarce will usually take other species. The annual band recovery and survival rates by sex and banding area are recorded (Tables 2–7). Chi-square tests of the data to Seber's model are also included.

TABLE 2. Summary of Band Recovery Rate and Survival for Adult Male Wigeon Banded at Gray Lodge Wildlife Area 1953–1967.

Year banded	Number banded	Number recovered	Recovery rate		Survival rate	
			Estimate	Standard deviation	Estimate	Standard deviation
1953	290	43	5.517	1.341	73.42	15.51
1954	623	79	4.187	0.728	49.42	9.98
1955	192	33	5.454	1.167	80.89	16.10
1956	586	85	4.742	0.723	74.85	18.56
1957	138	18	4.242	1.083	63.20	16.65
1958	359	50	3.875	0.742	93.65	19.56
1959	354	38	4.406	0.815	52.50	10.64
1960	589	71	4.420	0.683	67.46	11.84
1961	539	61	3.410	0.585	70.91	12.61
1962	556	62	4.043	0.634	63.12	11.10
1963	595	67	4.095	0.624	70.50	15.03
1964	305	31	2.843	0.616	55.87	15.55
1965	145	19	5.585	1.331	51.53	12.77
1966	610	89	4.955	0.732	57.26	9.00
1967	416	70	6.731	0.963	--	--
Mean	--	--	4.412	0.236	66.04	1.65

Mean 90% confidence interval for recovery rate: 4.03–4.80.
Mean 90% confidence interval for survival rate: 63.33–68.75.
Goodness of fit test that the data fit Seber's model: $\chi^2 = 73.96$, 75 d.f.
Mean life span as an adult: 2.32 ± 0.14 years.

TABLE 3. Summary of Band Recovery Rate and Survival for Adult Female Wigeon Banded at Gray Lodge Wildlife Area 1953–1967.

Year banded	Number banded	Number recovered	Recovery rate		Survival rate	
			Estimate	Standard deviation	Estimate	Standard deviation
1953	135	17	8.148	2.355	51.56	22.00
1954	464	40	3.373	0.803	104.95	46.36
1955	120	6	2.500	1.083	31.12	14.33
1956	473	38	3.214	0.729	84.62	31.79
1957	158	9	2.306	0.862	79.22	36.13
1958	257	11	1.665	0.602	35.75	14.13
1959	246	18	3.110	0.908	59.24	18.27
1960	521	37	3.669	0.740	53.55	14.58
1961	468	30	2.173	0.551	70.52	19.11
1962	466	28	3.318	0.709	35.38	10.01
1963	434	33	3.138	0.706	72.26	25.49
1964	178	11	2.575	0.871	52.27	26.41
1965	87	6	3.245	1.408	55.71	25.89
1966	412	27	3.204	0.771	34.09	10.12
1967	285	28	4.045	0.993	--	--
Mean	--	--	3.260	0.277	58.24	3.63

Mean 90% confidence interval for recovery rate: 2.81–3.71.
Mean 90% confidence interval for survival rate: 52.29–64.18.
Goodness of fit test that the data fit Seber's model: $\chi^2 = 26.69$, 29 d.f.
Mean life span as an adult: 1.66 ± 0.28 years.

TABLE 4. **Summary of Band Recovery Rate and Survival for Adult Male Wigeon Banded in Imperial Valley 1951–1961.**

Year banded	Number banded	Number recovered	Recovery rate		Survival rate	
			Estimate	Standard deviation	Estimate	Standard deviation
1951	123	23	9.756	2.675	58.42	17.36
1952	1006	154	4.824	0.659	78.15	8.32
1953	2117	284	4.765	0.416	61.76	6.51
1954	921	129	5.748	0.586	68.45	7.86
1955	1550	187	5.449	0.476	50.97	0.559
1956	681	89	3.888	0.510	50.62	6.49
1957	863	120	5.001	0.556	66.03	8.93
1958	1020	114	4.128	0.469	79.67	10.27
1959	200	24	5.538	1.130	58.74	12.63
1960	465	50	4.765	0.753	60.09	14.49
1961	746	93	4.438	0.610	48.03	8.56
Mean	--	--	5.386	0.331	63.00	2.00

Mean 90% confidence interval for recovery rate: 4.84–5.93.
Mean 90% confidence interval for survival rate: 59.71–66.28.
Goodness of fit test that the data fit Seber's model: $\chi^2 = 83.37$, 59 d.f.
Mean life span as an adult: 2.11 ± 0.25 years.

TABLE 5. **Summary of Band Recovery Rate and Survival for Adult Female Wigeon Banded in Imperial Valley 1951–1961.**

Year banded	Number banded	Number recovered	Recovery rate		Survival rate	
			Estimate	Standard deviation	Estimate	Standard deviation
1951	72	8	2.778	1.937	124.79	52.46
1952	584	47	2.968	0.675	47.85	11.23
1953	890	69	3.299	0.549	53.06	13.11
1954	274	23	4.034	0.936	58.18	16.28
1955	467	35	3.697	0.741	65.31	20.88
1956	258	15	2.194	0.672	47.20	15.64
1957	339	26	3.120	0.766	86.69	27.00
1958	362	19	2.624	0.686	65.61	36.43
1959	100	4	2.710	1.369	13.07	7.70
1960	233	23	6.581	1.534	52.24	20.79
1961	254	16	3.033	0.952	--	--
Mean	--	--	3.400	0.342	58.92	6.35

Mean 90% confidence interval for recovery rate: 2.84–3.96.
Mean 90% confidence interval for survival rate: 48.51–69.33.
Goodness of fit test that the data fit Seber's model: $\chi^2 = 26.51$, 20 d.f.
Mean life span as an adult: 1.58 ± 0.30 years.

TABLE 6. **Summary of Band Recovery Rate and Survival for Adult Male Wigeon Banded in Imperial Valley 1963–1969.**

Year banded	Number banded	Number recovered	Recovery rate		Survival rate	
			Estimate	Standard deviation	Estimate	Standard deviation
1963	625	74	4.800	0.855	53.57	9.37
1964	700	92	4.542	0.694	70.57	13.36
1965	320	39	4.570	0.862	73.04	14.51
1966	700	73	2.454	0.449	66.14	10.38
1967	705	85	4.417	0.607	63.74	10.13
1968	609	73	4.711	0.662	48.66	7.60
1969	622	93	5.216	0.696	--	--
Mean	--	--	4.249	0.287	62.62	2.11

Mean 90% confidence interval for recovery rate: 3.78–4.72.
Mean 90% confidence interval for survival rate: 59.15–66.09.
Goodness of fit test that the data fit Seber's model: $\chi^2 = 23.47$, 25 d.f.
Mean life span as an adult: 2.09 ± 0.31 years.

TABLE 7. **Summary of Band Recovery Rate and Survival for Adult Female Wigeon Banded in Imperial Valley 1963–1969.**

Year banded	Number banded	Number recovered	Recovery rate		Survival rate	
			Estimate	Standard deviation	Estimate	Standard deviation
1963	375	34	3.733	0.979	59.26	16.87
1964	300	27	2.872	0.808	98.04	41.32
1965	112	7	3.205	1.275	76.12	37.36
1966	300	12	1.548	0.561	37.94	14.67
1967	294	19	2.721	0.795	48.76	15.35
1968	391	30	4.279	0.918	79.96	27.10
1969	377	16	3.156	0.827	--	--
Mean	--	--	3.060	0.374	66.68	6.01

Mean 90% confidence interval for recovery rate: 2.45–3.67.
Mean 90% confidence interval for survival rate: 56.83–76.53.
Goodness of fit test that the data fit Seber's model: $\chi^2 = 8.99$, 11 d.f.
Mean life span as an adult: 2.20 ± 0.75 years.

Numerous studies of ducks and geese have shown that female mortality rates tend to be higher than male although their band recovery rates are lower than those of males. The assumption is that the female has a higher nonhunting mortality, particularly during the nesting period than that of the male. The male, in turn, has a higher harvest rate, thus the greater band recovery rate. Differential migration with the male moving into a high harvest area earlier than the female and hunter selectivity on ducks are two possible causes for this greater harvest rate. The data used in this report suggest that the American wigeon follows this pattern.

The mean band recovery rate for adult male wigeons banded at Gray Lodge is 4.42 ± 0.24% and the mean survival rate is 66.04 ± 1.65% (Table 2) as compared to the Gray Lodge female mean recovery rate of 3.26 ± 0.28% and mean survival rate of 58.24 ± 3.63% (Table 3). Average life span for adult males is 2.32 years and 1.66 years for adult females. The wigeon banded in Imperial Valley follow the same general pattern as those of Gray Lodge except for a slight difference in the survival rates of the 1963–69 samples. The male had a mean survival rate of 62.62 ± 2.11% (Table 6) whereas the female had a higher rate of 66.68 ± 6.01% (Table 7); however, the difference is not significant. Note that the standard deviation for the female is much greater than that of the male, because there are fewer females trapped and also fewer females shot than males. In turn, there are fewer female band recoveries, hence less precision, resulting in the greater standard deviation and confidence interval. The wide variation in annual recovery rates and survival rates (Tables 2–7) is mostly due to small sample sizes.

Estimates of parameters on an annual basis are subject to large sampling variances and therefore, average values are summarized (Table 8). Males have a significantly higher survival than females at Gray Lodge; however, no difference was found for wigeon banded in the Imperial Valley. Males banded in the Imperial Valley and at Gray Lodge had significantly higher recovery rates than females. In general, survival of the two banded populations appear to be similar. The effect of varying hunting regulations on survival could not be studied due to the large sampling variances of the annual estimates.

TABLE 8. Summary of Average Parameter Estimates for Adult Wigeon Banded in California.

		Gray Lodge*	Imperial Valley†
Survival rate	Males	66.04 ± 1.65	63.00 ± 2.00 62.62 ± 2.11
	Females	58.24 ± 3.63	58.92 ± 6.35 66.68 ± 6.01
Recovery rate	Males	4.41 ± .24	5.39 ± .33 4.25 ± .29
	Females	3.26 ± .28	3.40 ± .34 3.06 ± .37
Mean life span	Males	2.32 ± .14	2.11 ± .25 2.09 ± .31
	Females	1.66 ± .28	1.58 ± .30 2.20 ± .75

* 1953–67
† 1951–61 (top)
1963–69 (bottom)

During the period of the study no apparent trend in annual recovery rates was noted other than what might be expected from changes in hunting regulations.

To obtain an estimate of the average kill rate, the band reporting rate and the rate of crippling loss must be known. A band reporting rate of 50% was estimated from the results of the first year band recoveries of the recent reward band study on mallard conducted by Dr. Charles J. Henry, Migratory Bird and Habitat Research Laboratory, Laurel, Maryland. Charles Kimball of the Migratory Bird and Habitat Research Laboratory, Laurel, Maryland (pers. comm.), stated that there are too little hunter performance survey data to estimate crippling loss for wigeon. The overall rate of a 17% loss appears to be the best estimate for dabbling ducks except for the wood duck (*Aix sponsa*).

The average kill rate for adult male wigeons banded on Gray Lodge Wildlife Area is estimated by dividing the band recovery rate of 4.4% by the band reporting rate of 50% which yields the harvest rate at 8.8%, which in turn is adjusted for the 17% crippling loss which results in an average kill rate of 10.3%. This compares to 12.2% for adult males banded in Imperial Valley during the 1951–61 period and 9.9% during the later period of 1963–1969. The Gray Lodge female kill rate amounted to 7.6% compared to 8.0% for Imperial Valley female early period and 7.1% for the late period.

A survival rate of 66.04%, e.g., Gray Lodge males, indicates an overall mortality rate of 33.96%. By subtracting the 10.3% hunter kill rate from the 33.96% mortality rate, the data suggest a nonhunting mortality rate of 23.66% for males banded at Gray Lodge. The Gray Lodge females had an expected higher nonhunting mortality of 34.16%. The Imperial Valley wigeon mortality data are comparable to the Gray Lodge data.

Differences in the kill rate and the survival rate between the two wintering populations of wigeon are reasonable. Although their survival is not as high as the 70.77% found for adult male pintail wintering in California (Anderson and Sterling 1974), it is comparable to the continent-wide estimate of 62% suggested for adult male mallards (Anderson, pers. comm.).

SUMMARY

From 1951 through 1971 personnel of the California Department of Fish and Game banded or assisted in banding 32,097 American wigeon during the posthunting season period.

Seber's (1970) method for band recovery analysis was used to determine band recovery rate, survival rate and life span of wigeon populations wintering in California.

Over 50% of the wigeon harvest in the United States is concentrated in the Pacific Flyway and about 25% of the total harvest occurs in California.

There are two wigeon populations in California: those wintering in the Sacramento and San Joaquin valleys and those wintering in the Imperial Valley.

The main fall migration route of wigeon wintering in northern California funnels mainly through Washington, Idaho and Oregon to the Central Valley of California.

The Sacramento Valley is the main wintering area in California.

The wigeon migration to the Imperial Valley is slightly more easterly oriented than that of the northern California wigeon.

Utah, in the vicinity of the Great Salt Lake, is the most important band recovery area for the Imperial Valley wigeon population other than the Imperial Valley.

Since 1971, a marked decrease has occurred in the number of wigeon wintering in the Imperial Valley with a corresponding increase in Mexico.

The sex ratio of trapped samples of wigeon wintering in the Imperial Valley has more males at 70% than samples obtained in the Sacramento and San Joaquin valleys.

The true sex ratio of wigeon in the Sacramento Valley is probably close to the 55.0% males found in hunter bag checks and the 56.4% males found in the trap samples.

The mean recovery rate for adult male wigeons banded at Gray Lodge is 4.42 ± 0.24% and the mean survival rate is 66.04 ± 1.65% as compared to the Gray Lodge female mean recovery rate of 3.26 ± 0.28% and the mean survival rate of 58.24 ± 3.63%. The mean life span for adult males is 2.32 years and 1.66 years for adult females.

Although the Imperial Valley 1963–1969 samples show the female to have a slightly higher survival rate of 66.68 ± 6.01% as compared to 62.62 ± 2.11% for the male, it was not significant.

The mean kill rate for adult male wigeon banded at Gray Lodge is 10.3% compared to 12.2% for adult males banded in Imperial Valley 1951–1961 and 9.9% during the later period of 1963–1969. The Gray Lodge female kill rate amounted to 7.6% compared to 8.0% for Imperial Valley female early period and 7.1% for the late period.

The 10.3% kill rate for Gray Lodge males subtracted from their 33.96% mortality rate suggests a nonhunting mortality of 23.66% compared to the higher 34.16% for females banded at Gray Lodge.

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NOTES

A RANGE EXTENSION FOR THE LOGPERCH, *PERCINA MACROLEPIDA*, IN CALIFORNIA

Since the introduction of the (bigscale) logperch, *Percina macrolepida* Stevenson, into ponds on Beale Air Force Base in 1953, its spread south has been well documented (Farley 1972; Moyle, Fisher, and Li 1974). Its taxonomic status has been discussed by Sturgess (1976). This note documents its northward range expansion.

I collected bigscale logperch from the following locations during the spring of 1974: (i) the Feather River near Oroville, (ii) north of the Feather River's confluence with the Sacramento River, (iii) the Sacramento River just south of its junction with the Sutter Bypass, (iv) an irrigation canal on the M & R Gun Club near Butte City, (v) Hutchinson Creek west of Plumas Lake, (vi) Best Slough and Dry Creek about ½ mile from their junction with the Bear River, and, (vii) Miller and Blackwelder lakes (two of the original introduction sites).

In addition to these collections, logperch have been found to be present in Butte Creek (Calif. State Univ., Chico, Museum Collection) and the Yuba River near Honcut (Richard E. Painter, California Dept. of Fish and Game, pers. commun.). A more recent collection was made in September 1975, at Wilson Landing on the Sacramento River northwest of Chico, by Paul Maslin of the Calif. State University, Chico (pers. commun.).

These collections indicate that the logperch is quite capable of extending its range northward through the major river systems and their tributaries in California. Further studies may indicate an even more widespread northern distribution than this paper indicates.

The dispersal route of the logperch is not as reported previously (Shapovalov, Dill, and Cordone 1959; McKechnie 1966; Farley 1972). These authors suggested that the logperch emigrated northward from Miller and Blackwelder lakes to Hutchinson Creek, to Dry Creek, to the Yuba River, and then to the Feather River. But Polk (the third introduction site) and Blackwelder lakes drain into Dry Creek, which flows south to the Bear River. Miller Lake drains southward through Best Slough, which also flows to the Bear River. Bear River flows westward and enters the Feather River. During times of exceedingly high water, overflow from Best Slough may drain into Hutchinson Creek, which flows westward into Plumas Lake. This reservoir drains into the Feather River. It is highly unlikely that the logperch could extend its range northward by the route previously reported. Although Dry Creek does extend to the north of Miller, Polk, and Blackwelder lakes, it does not extend to the Yuba River. Any northward extension by Dry Creek is also effectively blocked by a small dam about one mile north of Polk Lake.

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NOTES ON THE FORAGING OF NESTING CASPIAN TERNS *HYDROPROGNE CASPIA* (PALLAS)

During a 1971 nesting study of the Caspian Tern in South San Francisco Bay, food habits data were collected (Gill 1971). Of interest was the recovery of 12 tagged rainbow trout (*Salmo gairdneri*) from the colony site, a 100 m X 10 m (109 X 10.9 yards) segment of salt evaporation pond levee approximately 19 km (11.8 miles) NW of San Jose, Santa Clara County. All tags were recovered between June 14–23, 1971 and with one exception all tags were recovered from regurgitated pellets at the nests sites. A single whole trout with the tag still attached was also recovered at the colony.

Eleven of the fish were part of a plant of 400 tagged catchable trout (avg 210–230 mm (8.2–9 inches) TL) released into Del Valle Reservoir, Alameda County, 29 km (18 miles) from the colony site on May 21, 1971. The twelfth tag was from a plant of 308 tagged catchable trout released into Coyote Reservoir, Santa Clara County, 62 km (37 miles) from the colony on April 30, 1971.

These two foraging site preferences were apparently restricted to only two of the colony's 200 nesting pairs. Seven tags from Del Valle Reservoir were recovered from one nest site while the remaining five tags, including the one Coyote Reservoir tag, were recovered from an adjacent nest site. These observations suggest that the foraging site preference of one pair was learned from the other.

Throughout the rest of the colony, remains of 21 additional rainbow trout were recovered. The nearest waters known to support rainbow trout, besides the previously mentioned, are upper Alameda Creek and Calaveras Reservoir, both approximately 13 km (8 miles) from the colony.

In addition to rainbow trout, 20 other fish species were collected at the colony site, including single specimens of largemouth black bass (*Micropterus salmoides*), black crappie (*Promoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), carp (*Cyprinus carpio*), and goldfish (*Carassius auratus*). However, of the 605 samples collected, the major food items were jack smelt (*Atherinopsis californiensis*) 33%, shiner perch (*Cymatogaster aggregatus*) 19%, and staghorn sculpin (*Leptocottus armatus*) 19%. Forage preferences for these typically estuarine species would be expected for terns nesting adjacent to an estuary.

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HELMINTH PARASITES IN AMERICAN COOTS FROM THE LOWER COLORADO RIVER

American coots (*Fulica americana*) are well known throughout their range in North America, however, few studies of the helminth parasites of coots have been conducted. Coots on the breeding grounds of Alberta were examined for helminths by Colbo (1965), while Roudabush (1942) examined coots in Iowa during the fall migration. Kinsella (1973) reported the helminth parasites of coots on their wintering grounds of Florida. In addition, parasites of coots have been noted by Cram (1930), Noble (1933), Gullion (1952a), Trainer and Fischer (1963), and MacDonald (1969). Although the coot is a common-to-abundant winter resident along the lower Colorado River (Eley 1975), no data have been available on coot parasite burden in this area.

This report lists the helminth parasites collected from 250 coots from the lower Colorado River (102 coots were collected between October, 1970 and January, 1971, and 148 coots were collected from October, 1971 to January, 1972). The birds were collected along 40.2 km (25 miles) of the Colorado River extending from Imperial Dam (Imperial County, California and Yuma County, Arizona) on the north to Moralos Dam (Yuma County, Arizona and Sonora, Mexico) on the south. The birds were collected by shooting and then frozen in plastic bags until necropsy. The nasal passages, mesenteries, air sacs, body cavity, heart, lungs, esophagus, proventriculus, gizzard, intestines, caecum, liver, kidneys, and reproductive organs were searched for helminth parasites. Helminths were preserved in 70% alcohol or 10% formalin. Trematodes, cestodes, and acanthocephala were stained in Semichon's carmine and mounted in Permount. Nematodes were cleared in glycerin alcohol and mounted temporarily in glycerin. Taxonomy of helminth parasites follows MacDonald (1969, 1974). Coots were aged by tarsal color (Gullion 1952b). The amount of subcutaneous fat of the coots was determined by methods similar to those of Mueller and Berger (1966).

Ten species of helminths were recovered from coots in this survey (Table 1). Of 114 (45.6%) parasitized coots, 73 contained only one species of parasite, 25 had two species, 14 had three species, and two coots had four

TABLE 1. Helminth Parasites Collected from 250 Coots in the Lower Colorado River Study Area.

Parasite	Hosts No.	Infected (%)	Parasites/Host Mean	Parasites/Host (Range)	Host Site
Trematoda					
Cyclocoelum mutabile	45	(18.0)	2.0	(1– 9)	Air sacs
Echinostoma chloropodis	1	(0.4)	2.0		Small intestine
Echinostoma revolutum	21	(8.4)	6.1	(1–29)	Caeca and small intestine
Notocotylus pacifera	10	(4.0)	3.3	(1–12)	Caeca
Cestoda					
Diorchis inflata	49	(19.6)	11.9	(1–72)	Intestines
Cloacotaenia megalops	5	(2.0)	11.8	(1–46)	Large intestine
Unidentified tapeworm	1	(0.4)	1.0		Small intestine
Nematoda					
Amidostomum fulicae	7	(2.8)	9.0	(2–30)	Gizzard-under lining
Acanthocephala					
Polymorphus minutus	1	(0.4)	2.0		Small intestine
Polymorphus trochus	32	(12.8)	6.6	(1–38)	Intestines

species of helminth parasites. *Polymorphus minutus* has not been previously recorded from the coot. *Strongyloides avium*, recovered by Cram (1930), and *Strongyloides* sp., found by Kinsella (1973), were absent from lower Colorado River coots. Kinsella (1973) called *Strongyloides* "a common parasite in coots," however, this classification may be premature.

Burrows of *Amidostomum fulicae* were observed in the gizzards of seven coots. Lesions caused by the attachment of *Diorchis inflata, Cloacotaenia megalops*, and *Polymorphus trochus* frequently were observed in the intestines of coots. Penetration of the worms usually was restricted to the mucosa of the intestines. However, in two coots, attachment of *Polymorphus trochus* caused hemorrhages, ecchymoses, and some ulceration. Histopathological examinations were not conducted.

The relationship between sex, age, and fat level of the host and the prevalence of parasites was investigated. *Polymorphus trochus* was found in 28 (21.8%) males and only 4 (3.3%) female coots ($p < .001$). *Cyclocoelum mutabile* was found in 28 (27.1%) of 103 first-year birds, 6 (7.1%) of 85 second-year birds, and 11 (17.7%) of 62 third-year or older coots. Significantly more first-year birds were parasitized with *Cyclocoelum mutabile* than second or third-year and older birds ($p < .05$). The prevalences of the other species of parasites were not related to the sex or age of the host. No relationship was found between the prevalence of parasites and the amount of subcutaneous fat on the coots.

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FIRST RECORD OF MOHAVE GROUND SQUIRREL (*CITELLUS MOHAVENSIS*) IN KERN COUNTY, CALIFORNIA

Historically, the Mohave ground squirrel (*Citellus mohavensis*) occurred in the Mojave Desert west to Palmdale, north to Haiwee Mesa, and south to Rabbit Springs near Hesperia (Leach, et al. 1974). However, in a recent survey, these animals were found in only three locations in San Bernardino County and at one location in Los Angeles County (Hoyt 1972).

The first Mohave ground squirrel seen at our study area (R37E, T32S, Sec. 9) at the junction of C and F Streets, California City, Kern County, California, was observed between 1130 and 1330 hours March 9, 1975. It was first seen under a creosote bush (*Larrea divaricata*) feeding on bird seed scattered from cleaning small mammal traps, some 10 m (33 ft) from our tents. After observing the animal through 7X35 binoculars, it was then photographed for a permanent record (Figure 1). These 35 mm color slides are on file at The Vertebrate Collections, Biology Department, California State University, Fresno.

FIGURE 1. This Mohave ground squirrel represents the first recent record of this animal for Kern County, California. Photo by Randy Patrick.

Hoyt (1972) found no current record of the Mojave ground squirrel in Kern County, although it was located north of our area at China Lake Naval Weapons Center, San Bernardino County, and at Keels Ranch near Palmdale in Los Angeles County.

This squirrel utilized a burrow system similar to that described by Bartholomew and Hudson (1961). In addition to the burrow entrance under the creosote bush, the animal utilized a second burrow located in the open about 6 m from the creosote bush. It disappeared underground at the base of the creosote bush after being photographed, and after about 30 min reappeared at the second burrow in the open. The squirrel appeared at irregular intervals for 2 hr to feed on the bird seed scattered near the burrow entrance for it.

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SOUTHERN RANGE EXTENSIONS OF THE BLUE ROCKFISH, *SEBASTES MYSTINUS;* THE FLAG ROCKFISH, *S. RUBRIVINCTUS;* AND THE SHORTBELLY ROCKFISH, *S. JORDANI*

During 1974, three species of rockfish were collected aboard the California Department of Fish and Game Research vessel ALASKA off the Pacific coast of northern and central Baja California. These fish were captured in areas south of their reported geographic ranges.

On two separate occasions, blue rockfish, *S. mystinus*, were captured by hook and line. The first specimen was taken just south of Punta Baja (lat 29° 54′ 42″ N, long 115° 49′ 00″ W) in 25.6 m (14 fm) of water on August 20, 1974. The second specimen was taken off Punta San Quintín (lat 30° 20′ 54″ N, long 116° 05′ 36″ W) in 45.7 m (25 fm) of water on August 21, 1974. The second specimen measured 378 mm (14.9 inches) total length (TL). No measurement was taken on the first specimen. Both of these captures were south of Punta Santa Tomás (lat 31° 33′ 30″ N, long 116° 42′ 00″ W) the previous southern range limit of blue rockfish (Miller and Lea 1972; Phillips 1957). The Punta Baja specimen represents a range extension of about 203.8 km (110 nautical miles).

Two specimens of flag rockfish, *S. rubrivinctus*, were taken off Punta San Quintín (lat 30° 20′ 54″ N, long 116° 05′ 36″ W) in 45.7 m (25 fm) of water on August 21, 1974. The two flag rockfish measured 328 mm (12.9 inches) TL and 291 mm (11.5 inches) TL. Previously, the southernmost occurrence of this species was reported by Rosenblatt and Chen (1972) as being off Cabo Colnett (lat 31° 03′ N, long 116° 22′ W). The specimens captured off Punta San Quintín represent a range extension of 72.3 km (39 nautical miles). A shortbelly rockfish, *S. jordani*, was captured in a bottom trawl off Punta Baja (lat 30° 03′ 12″ N, long. 115° 53′ 00″ W) in 45.7 m (25 fm) of water on August 21, 1974. This specimen measured 90 mm (3.5 inches) TL. Miller and Lea (1972) reported the southern range limit as Cabo Colnett. The shortbelly rockfish captured off Punta Baja represents a range extension of 109.3 km (59 nautical miles).

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—Richard A. Klingbeil, Marine Resources Region and Eric H. Knaggs, Operations Research Branch, California Department of Fish and Game, Long Beach 90802. *Accepted August 1975.*

Calif. Fish and Game (62)2: 161–162. 1976.

A SWIMMING CRAB, *EUPHYLAX DOVII* STIMPSON 1860, NEW TO THE MARINE FAUNA OF CALIFORNIA

On 30 August 1974, during a series of otter trawls conducted by the Southern California Coastal Water Research Project in Santa Monica Bay, a specimen of the purple swimming crab, *Euphylax dovii* Stimpson 1860, was collected near Playa del Rey. The specimen was taken in a 15 min tow at lat 33°56.15′ N, long 118°26.75′ W, in 11 m (36 ft) of water. This species of swimming crab is common in the stomach contents of tuna caught throughout the Central American Pacific at distances of up to 190 km (115 miles) offshore (Suhl 1955; Alverson 1963). Although the crab has been taken at great distances offshore, indicating a high degree of mobility, it has only been recorded as far north as Bahía de Manzanillo, Colima, Mexico (Garth and Stephenson 1966). Thus, our observation adds almost 2,200 km (1320 miles) to the known range of the species.

Three other swimming crabs have been reported in California waters, *Portunus xantusii* (Stimpson 1860), *Callinectes arcuatus* Ordway 1863, and *Callinectes bellicosus* (Stimpson 1859). These and other distributional information can be found in Garth and Stephenson 1966. The purple swimming crab, *Euphylax dovii* (Figure 1) is easily distinguished from these other, more common forms because of its narrow, T-shaped rostrum, its very long eye stalks (with orbits occupying nearly the whole anterior border of the carapace), and its reddish-purple carapace.

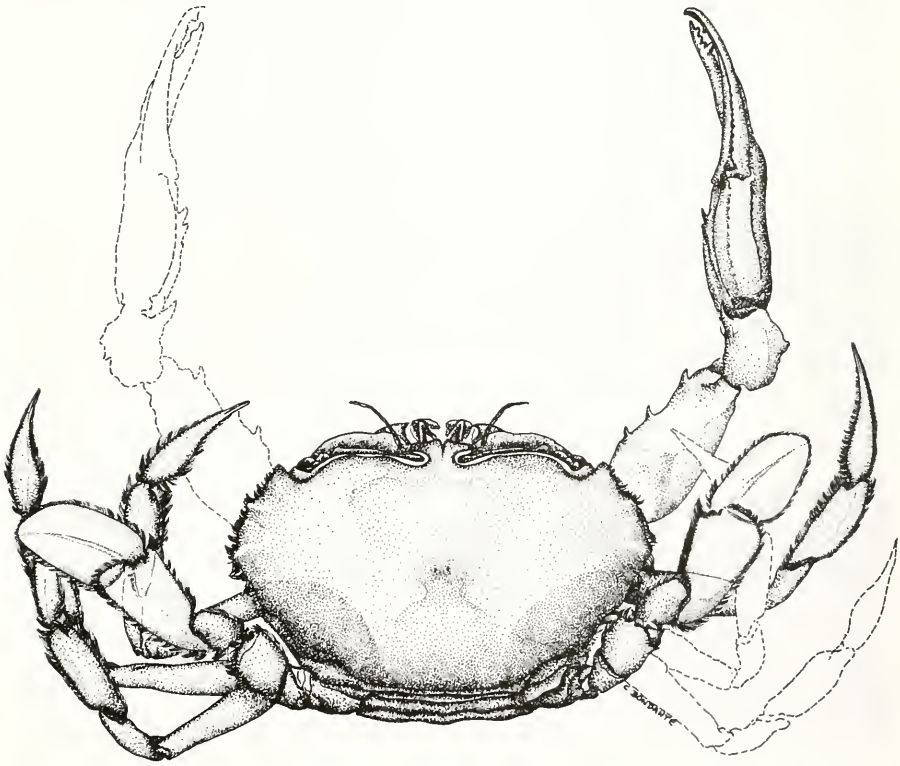

FIGURE 1. Dorsal view of *Euphylax dovii* taken in Santa Monica Bay, 30 August 1974. Figure drawn by Christine Bondante.

The specimen taken by project personnel was an adult female 41 mm (1.6 inches) long and 67.3 mm (2.6 inches) in breadth. According to size information in Garth and Stephenson (1966), this specimen is a size record for the female of this species—the largest female taken prior to this date was 25.9 mm (1.0 inch) long and 41.8 mm (1.6 inches) in breadth.

The identification of this specimen was verified by J. S. Garth of the Allan Hancock Foundation and the specimen is being maintained in the reference collection of the Coastal Water Research Project in El Segundo, California.

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—Jack Q. Word, Southern California Coastal Water Research Project, El Segundo, California 90245.

Calif. Fish and Game (62)2: 163–164. 1976.

FIRST RECORD OF ALBINISM IN THE LEOPARD SHARK (*TRIAKIS SEMIFASCIATA* GIRARD)

A leopard shark (*Triakis semifasciata* Girard, 1854) caught in San Pablo Bay, California, on August 22, 1972, appears to be the first known albino individual of this species. It was caught by James Sturgis, who was fishing with rod and line about 1.6 km (1 mile) off Hamilton Field, Marin County (ca. lat. 38°04'N, long. 122°27'W), in water about 3 m (10 ft) deep.

Recognizing the shark as a rarity, Mr. Sturgis gave it to California State Fish and Game Warden Alfred F. Giddings, who promptly had it frozen. Wallace E. Strohschein delivered the specimen, in excellent condition, on September 9, 1972, to the Department of Ichthyology, California Academy of Sciences, where it is catalogued as CAS 27159.

Immediately after thawing, the leopard shark, a half-grown male, measured 60 cm (23.6 inches) in total length and weighed 0.85 kg (1.9 lb). It was entirely white except for barely discernible black saddlemarks (Figure 1). None of the other black markings that characterize the normal coloration of this species, mid-dorsal intersaddle marks, inferior intersaddle marks, or subsaddle marks, as illustrated by Schott (1964), could be distinguished. The irises of the eyes were pink at the time of its capture (Alfred F. Giddings, pers. commun.), as in a true albino. The specimen had no apparent structural abnormality. Its vertebral count appears to fall within the normal variation of this species. As determined from radiographs, its total vertebral count was 140 (85 precaudal + 55 caudal). Ten leopard sharks (5 males, 5 females) from San Francisco Bay had total vertebral counts averaging 143.0 (90.7 precaudal + 52.3 caudal). One of these had a total count (140) identical to that of the albino specimen, but had 88 precaudal + 52 caudal vertebrae. Springer and Garrick (1964) recorded a count of 136 (84 + 52) in their single example of the leopard shark.

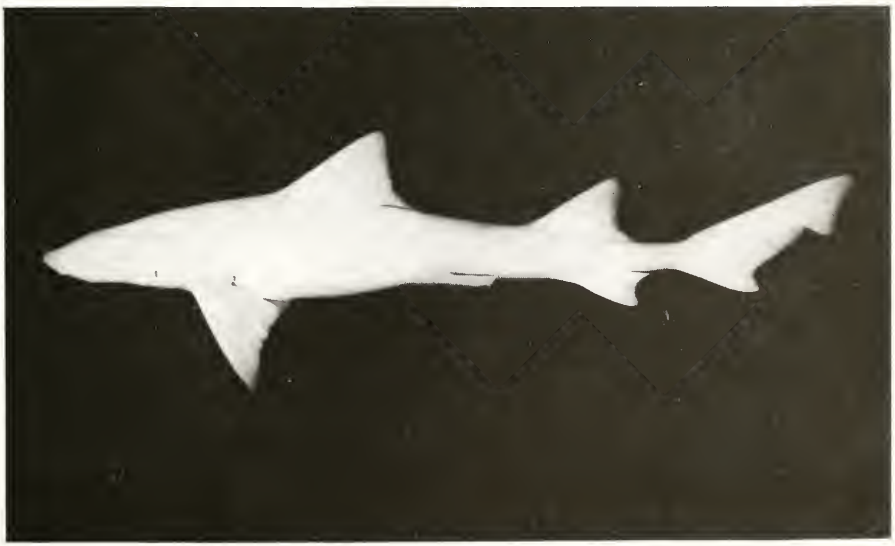

FIGURE 1. Albino leopard shark (*Triakis semifasciata* Girard), CAS 27159, 60 cm (23.6 inches) TL, 0.85 kg (1.9 lb), caught by James Sturgis, 22 August 1972, in San Pablo Bay, California. Photograph by W. I. Follett, 10 September 1972.

Albinism in the sevengill shark (*Notorynchus maculatus* Ayres) was recorded by Herald (1953) and in the gray smoothhound (*Mustelus californicus* Gill), by Herald, Schneebeli, Green, and Innes (1960), Cohen (1973), and Talent (1973). Records of albinism in elasmobranchs of other regions were noted by Dawson (1964, 1971), Follett and Dempster (1966), McKenzie (1970), and Nakaya (1973).

ACKNOWLEDGMENTS

I thank Alfred F. Giddings and Wallace E. Strohschein of the California Department of Fish and Game, and James Sturgis of Santa Venetia, for the acquisition of the albino leopard shark; and three members of the staff of the California Academy of Sciences: Lillian J. Dempster for assistance with the manuscript, Maurice C. Giles for an enlargement of the photograph, and James E. Gordon for radiographs of the albino specimen and of the comparative material.

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—W. I. Follett, California Academy of Sciences, Golden Gate Park, San Francisco, California 94118. *Accepted August 1975.*

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FISH AND GAME COMMISSION
HEARINGS ON MAMMAL HUNTING SEASONS

NOTICE IS HEREBY GIVEN that the Fish and Game Commission will meet on April 2, 1976, at 9:00 a.m., in the Auditorium of the Resources Building, 1416 Ninth Street, Sacramento, California, to receive recommendations from its own officers and employees, from the Department of Fish and Game and other public agencies, from organizations of private citizens, and from any interested persons as to what, if any, orders should be made relating to mammals, or any species or variety thereof for the 1976 hunting season.

Notice is further given that the Fish and Game Commission will meet on April 30, 1976, at 9:00 a.m., in Room B-109 of the State Building, 1350 Front Street, San Diego, California, for public discussion of and presentation of objections to the proposals presented to the commission on April 2, 1976, and after consideration of such discussion and objections the commission shall publicly announce the regulations it proposes to make relating to mammals, or any species or variety thereof, for the 1976 hunting season.

Notice is also given that the Fish and Game Commission will meet on May 28, 1976, at 9:00 a.m., in Room 1138, New State Building, 107 S. Broadway, Los Angeles, California, to hear and consider any objections to its determinations or proposed orders in relation to mammals for the 1976 hunting season; such determinations resulting from hearing on April 30, 1976. This notice is published in accordance with provisions of Section 206 of the Fish and Game Code.

FISH AND GAME COMMISSION
Leslie F. Edgerton
Executive Secretary

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